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AFTAC/USAF ltr 28 Feb 1972

LONG RANGE SEISMIC MEASUREMENTS

KNICKERBOCKER

26 MAY 1967

Prepared for

AIR FORCE TECHNICAL APPLICATIONS CENTER

Washington, D. C.

9 FEBRUARY 1968

By

TELEDYNE, INC.

Under

Project VELA UNIFORM

Sponsored By

ADVANCED RESEARCH PROJECTS AGENCY
Nuclear Test Detection Office
ARPA Order No. 624

LONG RANGE SEISMIC MEASUREMENTS

KNICKERBOCKER

9 February 1968

SEISMIC DATA LABORATORY REPORT NO. 208

AFTAC Project No.:	VELA T/6702
Project Title:	Seismic Data Laboratory
ARPA Order No.:	624
ARPA Program Code No.:	5810
Name of Contractor:	TELEDYNE, INC.
Contract No.:	F 33657-67-C-1313
Date of Contract:	2 March 1967
Amount of Contract:	$ 1,736,617
Contract Expiration Date:	1 March 1968
Project Manager:	William C. Dean (703) 836-7644

P. O. Box 334, Alexandria, Virginia

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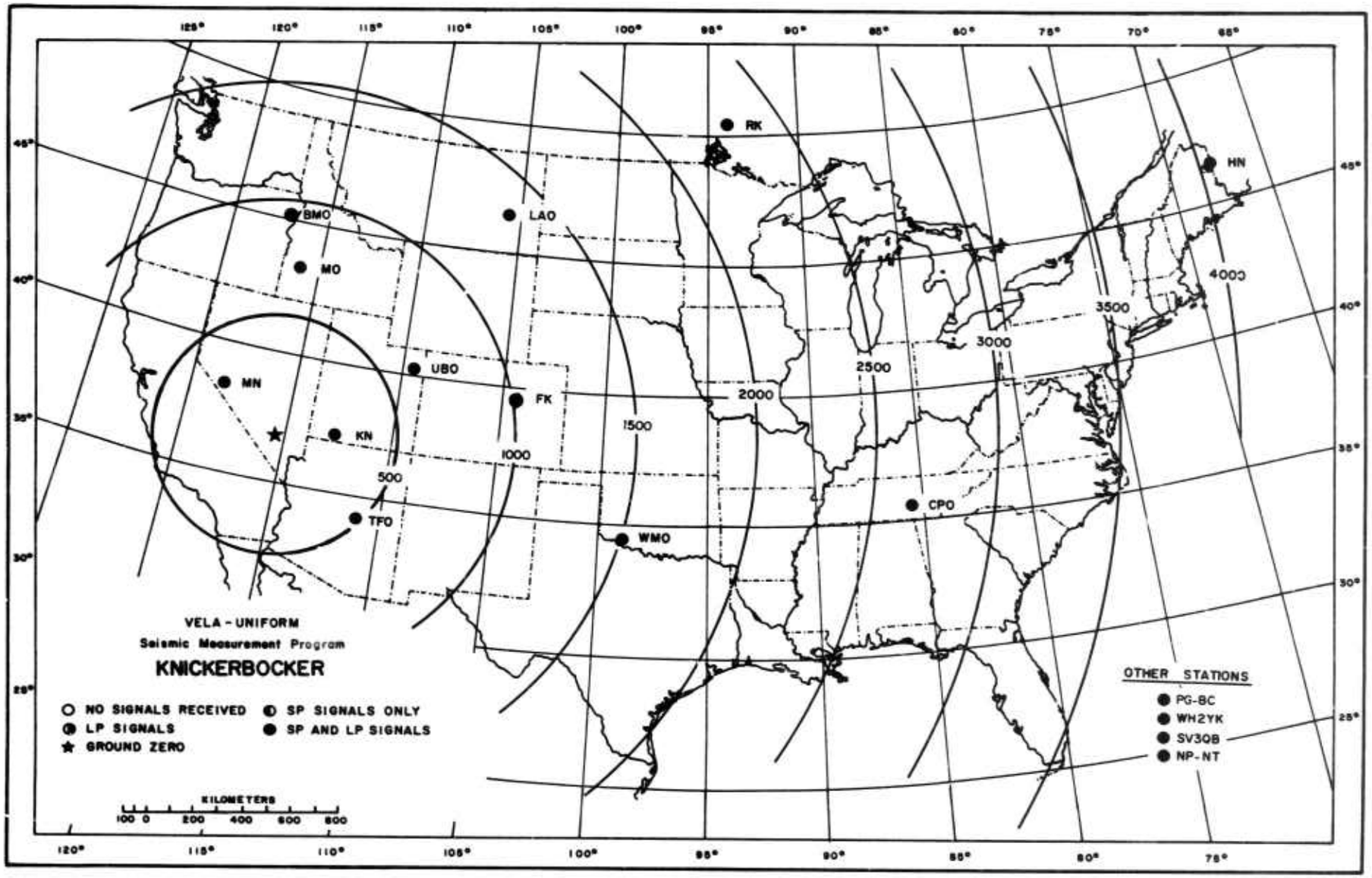
TABLE OF CONTENTS

KNICKERBOCKER

EVENT DESCRIPTION

DATE:		26 May 1967
TIME OF ORIGIN:		15:00:00.0Z
YIELD:		
MAGNITUDE:		5.54 ± 0.42
LOCATION:		
	SITE:	Nevada Test Site, Area U20d
		GEOGRAPHIC COORDINATES:
		Latitude: 37° 14' 53.0" N
		Longitude: 116° 28' 49.0" W
ENVIRONMENT:		
	GEOLOGIC MEDIUM:	RHYOLITE
	SURFACE ELEVATION:	6250 ft.
	SHOT ELEVATION:	4170 ft.
	SHOT DEPTH:	2080 ft.
COMPUTED EPICENTER:		ALL STATIONS
		GEOGRAPHIC COORDINATES:
		Latitude: 37° 06' 00.0" N
		Longitude: 116° 36' 36.0" W
	TIME OF ORIGIN:	15:00:01.5Z
	DEPTH CONSTRAINED TO:	0 km.
	EPICENTER SHIFT:	17.6 km S 22° W



Recording Stations and Signals Received

Figure 1

INTRODUCTION

A long range seismic measurement (LRSM) program and several larger seismographic observatories were established under VELA-UNIFORM to record seismological data resulting from natural seismic activity and a planned series of U.S. underground nuclear tests. The LRSM teams are mobile and occupy locations selected to provide optimum data from events of special interest; the observatories are permanent installations as follows:

Wichita Mountains Seismological Observatory (WMSO)
Lawton, Oklahoma

Uinta Basin Seismological Observatory (UBSO)
Vernal, Utah

Tonto Forest Seismological Observatory (TFSO)
Payson, Arizona

Large Aperture Seismic Array (LASA)
Billings, Montana

The purpose of this report is to provide an analysis of data resulting from the KNICKERBOCKER event recorded by the LRSM teams and the VELA observatories and a preliminary summary of data reported by other permanent and temporary seismographic stations.

INSTRUMENTATION AND PROCEDURE

The instrumentation at each of the LRSM locations consists of three-component short-period and three-component long-period seismographs. In general, data are recorded on 35 millimeter film and on one-inch 14-channel magnetic tape, although recently more portable instrumentation has been incorporated which records only on magnetic tape. The stations are all equipped to record

WWV continuously to provide accurate time control. Calibration is accomplished once each day and just prior to each shot at the operational settings. Pertinent information useful for analysis of LRSM data is available to qualified users of this data and is contained in Technical Report 65-43, "Interpretation and Usage of Seismic Data, LRSM Program." General information on LRSM van and portable system equipment and operation is given in Technical Report 66-27, "The LRSM Mobile Seismological Laboratory," and 65-74, "A Portable Seismograph." Copies of these reports may be obtained from DDC. The AD control number of Technical Report 66-27 is 480343. All the observatories have both long-period and short-period, three-component instrumentation, in addition to their other specialized facilities.

Station information is presented in Table 3. This includes the station name and code; the geographic coordinates; the distances and azimuths involved; the station elevations; and the type of instruments in use at each location. Reprensentative instrumental response curves are shown in Appendix II(B), II(C), and II(D) of the BOURBON shot report, SDL Report No. 186, available from DDC as AD 816273.

The procedures used in measuring amplitudes and the unified magnitude are shown in Appendices II(A) and I(B), respectively, of the BOURBON shot report. The distance factors (B) beyond 16° are from Gutenberg and Richter*. For distance less than 16° values were read from a curve in the Gutenberg and Richter paper

*Gutenberg, B. and Richter, C.F., Magnitude and Energy of Earthquakes, Ann. Geofis., 9 (1956), pp. 1-15.

back to 10° and then extrapolated to 2°, using an inverse cube relationship. An additional magnitude for less than 16° was computed using a method describe by Evernden**. (Figure 3)

A standard hypocenter location program for a digital computer is used to determine the location using data from all stations analyzed. Best-fit values of latitude, longitude, and time of origin are determined statistically by a least-squares technique. This utilizes a Jeffreys-Bullen travel-time curve as modified by Herrin in 1961 on the basis of Pacific surface-focus recordings. Precision of the computation is limited primarily by the accuracy of arrival times, the validity of the standard travel-time curve, and by local velocity deviations. This method is based on P-wave arrivals with depth constrained to zero.

DATA AND RESULTS (LRSM AND VELA OBSERVATORIES)

The parameters of the KNICKERBOCKER event and a summary of the seismic evaluation is shown on the Event Description page. The operational status of the 16 LRSM stations and observatories is given in Table 1, and illustrated in Figure 1.

Table 2 summarizes the measurements made of the principal phases from the KNICKERBOCKER event at the LRSM and VELA stations. Included are the Pn and P arrival times, the maximum amplitudes (A/T) of the Pn and P motion and other phases as seen on the short-period instruments. Long-period Love and Rayleigh wave

**Evernden, J.F., Magnitude Determination at Regional and Near Regional Distances in the United States, AFTAC/VELA Seismological Center Technical Report VU-65-4A,(1965),pp.6,13.

motion are also tabulated in (A/T) form. In addition, the individual station Rayleigh wave areas (mm^2) are indicated as measured on the LPZ only. Although reduced to 1K magnification, they have not been normalized to any magnitude. Sixteen stations recorded short-period and long-period signals.

The unified magnitudes determined from the LRSM and VELA observatories are shown in Figure 2. The average magnitude is 5.54 ± 0.42. The adjusted unified magnitude is 5.23 ± 0.40.

The travel-time residuals from the Pn and P phases are shown in Figure 4. Figures 5 through 9 illustrate plots of the amplitudes of P, Pg, Lg, LQ, and LR.

Attached to the report are illustrative seismograms showing the signals recorded at four stations. The most distant station analyzed that recorded KNICKERBOCKER was NP-NT at a distance of 4350 kilometers.

Code	Station	Distance (km)	Inst.	Magnification (k) Film x 10	Phase	Travel Time Observed (min)	Travel Time Observed (sec)	Travel Time (O-C) Computed (min)	Travel Time (O-C) Computed (sec)	Period T (sec)	Maximum Amplitude A/1	Magnitude (m) mb	Magnitude (m) ms	Area (mm^2) LPZ
NR-NY	Nice, Navada	167	SPZ	0.68	Pn	00	53.4	00	32.34	0.46	4262	6.69	6.26	
			SPZ		Pg	00	34.2			---	---			
			SPT	0.738	Lg					0.6	8326			
			LPZ	1.1	LR					14.0	3720			1063.64
KN-U1	Kanab, Utah	326	SPZ	2.11	Pn	00	49.6	00	48.88	0.65	1450	5.82	5.51	
			SPZ	1.76*	Pg	00	56.8			6.6	7179			
			SP1	2.112	Lg					0.6	4527			
			LPT	2.66	LQ					12.0	1074			
			LPZ	1.0	LR					12.0	3364			510.00
TFSO	Tantu Parast Seismological Observatory, Arizona	574	SPZ-60	10.0	Pn	01	21.6	01	20.68	0.3	143	5.56	5.22	
			SPZ-60	5.6	a	01	25.6			0.6	112			
			SPZ-60	5.5	Pg	01	26.8			0.55	648			
			SPR	6.0	Lg					(1.0)	(050)			
			SPE	5.5	Lg					1.0	773			
			LPN	2.5	LQ					(13.0)	(177)			
			LPE	2.0	LQ					(11.0)	(185)			
			LPZ		LR					---	---			
MO-10	Mountain Home, Idaho	647	SPZ	22.6	Pn	01	31.0	01	29.76	0.5	69	5.40	5.01	
			SPZ	22.6	a	01	53.1			0.7	152			
			SPZ	22.6	Pg					---	---			
			SP1		Lg					---	---			
			LP1		LQ					---	---			
			LPZ	1.7	LR					(14.3)	(372)			237.14
UBSO	Uinta Basin Seismological Observatory, Utah	691	SPZ-10	4.8	Pn	01	38.4	01	38.37	0.8	450	6.26	5.72	
			SPZ-10	4.8	a	01	50.9			0.7	965			
			SPZ-10	4.8	Pg	01	56.0			0.6	1066			
			SPN	5.0	Lg					0.0	817			
			SPE	5.0	Lg					0.8	1249			
			LPN	2.0	LQ					16.0	373			
			LPE	2.13	LQ					15.0	218			
			LPZ	1.94	LR					12.5	678			231.96
BMSO	Blue Mountains Seismological Observatory, Oregon	847	SPZ	760*	Pn	01	57.0	01	55.06	---	---			
			SPR		Lg					---	---			
			SPE		Lg					---	---			
			LPE	0.6	LQ					(12.0)	(1604)			
			LPZ	8.6	LR					15.0	230			212.21
FK-CO	Franktown, Colorado	1081	SPZ	61.0	Pn	02	(25.4)	02	24.30	0.8	76.0	6.15	4.67	
			SPZ	61.0	a	02	27.3			0.6	58.8			
			SPZ	61.0	PP	02	34.5			0.0	81.3			
			SPZ	61.0	Pg	03	01.0			(1.0)	(686)			
			SP1	46.9	Lg					1.8	1075			
			LP1		LQ					---	---			
			LPZ	1.31	LR					11.0	2266			438.93
LAO	Subarray, A0-10, Montana	1348	SPZ	42.9	Pn	02	(56.6)	02	56.66	1.0	40.8	5.40	4.60	
			SPZ	42.9	e	03	10.6			1.2	156			
			SPZ	42.6	(Pg)	03	44.6			0.75	68.6			
			LPR	**	LQ					14.0				
			LPE	**	LQ					(14.0)				
			LPZ	**	LR					16.0				
WMSO	Wichita Mountains Seismological Observatory, Oklahoma	1635	SPZ-8	130	P	03	(33.0)	03	31.21	1.2	86.6	5.35	5.06	
			SPZ-6	130	Pg	04	37.8			1.2	108			
			SPR	130	Lg					2.1	430			
			SPE	125	Lg					1.8	65.5			
			LPR	11.9	LQ					19.0	50.6			
			LPZ	1.9	LR					16.0	536			315.79
PB-BC	Prince George, British Columbia, Canada	1620	SPZ	206	P	04	(05.8)	04	03.68	1.2	253	5.30		
			SPZ	209	PP	04	21.6			1.0	103			
			SPR	198	Lg					2.3	101			
			SP1	221	Lg					2.3	85.4			
			LPN	52.5	LQ					7.5	150			
			LP1	57.5	LQ					(12.5)	(200)			
			LPZ	7.0	LR					10.5	268			217.85
RK-ON	Dad Lake, Ontario, Canada	2355	SPZ	41.3	P	04	48.0	04	49.14	(1.0)	(68.1)	(5.11)		
			SPZ	41.3	a	04	52.4			(1.0)	(182)			
			SPT	48.8	Lg					(1.5)	(38.7)			
			LPT	51.0	LQ					(15.0)	(82.0)			
			LPZ	9.86	LR					(13.0)	(206)			137.94
LP60	Cumberland Plateau Seismological Observatory, Tennessee	2766	SPZ	***	P	05	25.0	05	25.56					
			LPR	4.0	LQ					15.0	108			
			LPE	2.6	LQ					14.0	20.6			
			LPZ		LR					---	---			
WHZYK	Whitehorse, Yukon Territory, Canada	2917	SPZ	176	P	06	39.9	05	32.17	1.0	(16.6)	(5.71)		
			LPZ	176	w	05	41.4			0.75	17.0			
			SPR	179	n	05	54.6			1.0	14.0			
			SPE	179	a	06	01.6			0.6	14.1			
			LPT	17.8	S	10	16.0			(18.0)	(15.1)			
			SPT	168	Lg					(1.8)	(18.2)			
			LPT	17.8	LQ					(16.0)	(157)			
			LPZ	10.4	LR					16.0	272			436.90
NR-ME	Houlton, Maine	4091	SPZ	95.3	P	07	(10.2)	07	11.12	0.8	40.5	5.13		
			LP1	36.9	LQ					18.6	82.3			
			LPZ	25.2	LR					(16.0)	(57.6)			160.00
SY3Q6	Schaffarvilla, Quebec, Canada	4204	SPZ	103.2	P	07	(18.8)	07	19.62	1.0	43.6	6.14		
			SPR	105.8	Lg					(2.1)	(56.0)			
			SP1	103	Lg					(2.1)	(38.0)			
			LPR	30.4	LQ					(15.0)	(18.5)			
			LP1	34.4	LQ					(16.0)	(12.5)			
			LPZ	17.6	LR					14.0	74.8			344.69
RP-NT	Mould Bay, Northwest Territories, Canada	4350	SPZ	336	P	07	31.2	07	30.36	(0.6)	(50.8)	(6.11)		
			SPZ	336	e	07	(35.0)			(0.6)	(27.6)			
			SPZ	336	a	07	49.2			(0.6)	(20.6)			
			SPZ	336	PP	08	59.8			1.4	28.6			
			SPZ	374	PcP	09	(42.5)			8.8	6.8			
			SPT	553	Lg					2.8	73.8			
			LPT	18.8	LQ					18.8	78.8			
			LPZ	10.7	LR					18.8	88.8			294.89

--- Maximum Amplitude Clipped On Film and Tape
( ) Doubtful Values or Phases
* Measurements Made From Playouts
** Magnification Questionable
*** Film Not Received, No Calibration on Tape

Principal Phases

Table 2

Code	Station	Distance (km)	Geographic Latitude	Geographic Longitude	Elev. (km)	Computed Azimuth		Installed Azimuth		Large or Small SP	LP Inst.
						Epi. Sta.	Sta. Epi.	Radial	Tang.		
MN-NV	M Nevada	197	38° 26" 10' N	118° 08" 53' W	1.52	312°	131°	308°	38°	L	*
KN-UT	Kanab, Utah	326	37° 01" 22' N	112° 49" 39' W	1.74	93°	276°	95°	185°	L	*
*TFSO	Tonto Forest Seismological Observatory, Arizona	574	34° 17" 12' N	111° 16" 03' W	1.49	123°	306°	90°	0°	JM	*
MO-IO	Mountain Home, Idaho	647	43° 04" 19' N	116° 15" 56' W	0.79	2°	182°	359°	89°	L	*
*UBSO	Uinta Basin Seismological Observatory, Utah	691	40° 19" 18' N	109° 34" 07' W	1.60	58°	243°	90°	0°	JM	*
*BMSO	Blue Mountains Seismological Observatory, Oregon	847	44° 50" 56' N	117° 18" 20' W	1.19	356°	175°	0°	90°	JM	*
FK-CO	Franktown, Colorado	1081	39° 35" 12' N	104° 27" 42' W	1.80	72°	260°	79°	169°	L	*
*LAO	Subarray A0-10, Montana	1348	46° 41" 19' N	106° 13" 20' W	0.90	36°	223°	90°	0°	HSZ	*
*WMSO	Wichita Mountains Seismological Observatory, Oklahoma	1635	34° 43" 05' N	98° 35" 21' W	0.51	95°	285°	90°	0°	JM	*
*PG-BC	Prince George, British Columbia, Canada	1920	53° 59" 50' N	122° 31" 23' W	0.91	348°	164°	110°	200°	L	*
RK-ON	Red Lake, Ontario, Canada	2355	50° 50" 20' N	93° 40" 20' W	0.37	42°	239°	58°	148°	S	*
*CPSO	Cumberland Plateau Seismological Observatory, Tennessee	2766	35° 35" 41' N	85° 34" 13' W	0.57	84°	283°	90°	0°	JM	*
WH2YK	Whitehorse, Yukon Territory, Canada	2917	60° 41" 41' N	134° 58" 02' W	0.85	339°	145°	325°	55°	L	*
HN-ME	Houlton, Maine	4091	46° 09" 43' N	67° 59" 09' W	0.21	60°	274°	93°	183°	S	*
*SV3QB	Scheffervill[illegible], Quebec, Canada	4204	54° 48" 39' N	66° 45" 00' W	0.58	46°	263°	139°	229°	S	*
NP-NT	Mould Bay, Northwest Territories, Canada	4350	76° 15" 08' N	119° 22" 18' W	0.06	359°	176°	359°	86°	JMZ S	*

*Seismometers not orientated toward NTS.

Recording Site Information
Table 3

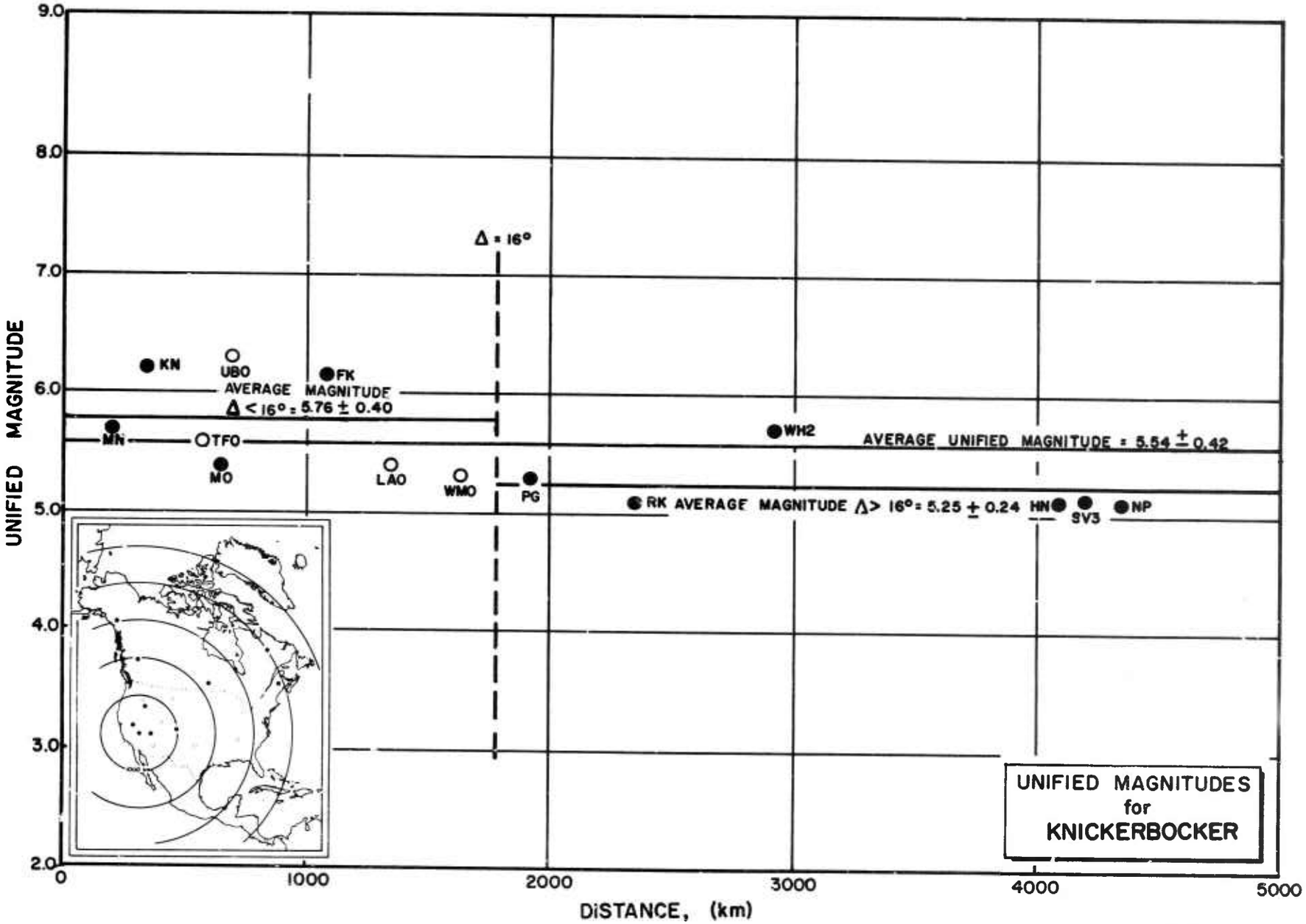

9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
UNIFIED MAGNITUDE
Δ = 16°
KN
UBO
FK
AVERAGE MAGNITUDE
Δ < 16° = 5.76 ± 0.40
MN
TFO
MO
LAO
WMO
PG
WH2
AVERAGE UNIFIED MAGNITUDE = 5.54 ± 0.42
RK AVERAGE MAGNITUDE Δ> 16° = 5.25 ± 0.24
HN
SV3
NP
UNIFIED MAGNITUDES
for
KNICKERBOCKER
0
1000
2000
3000
4000
5000
DISTANCE, (km)

Figure 2

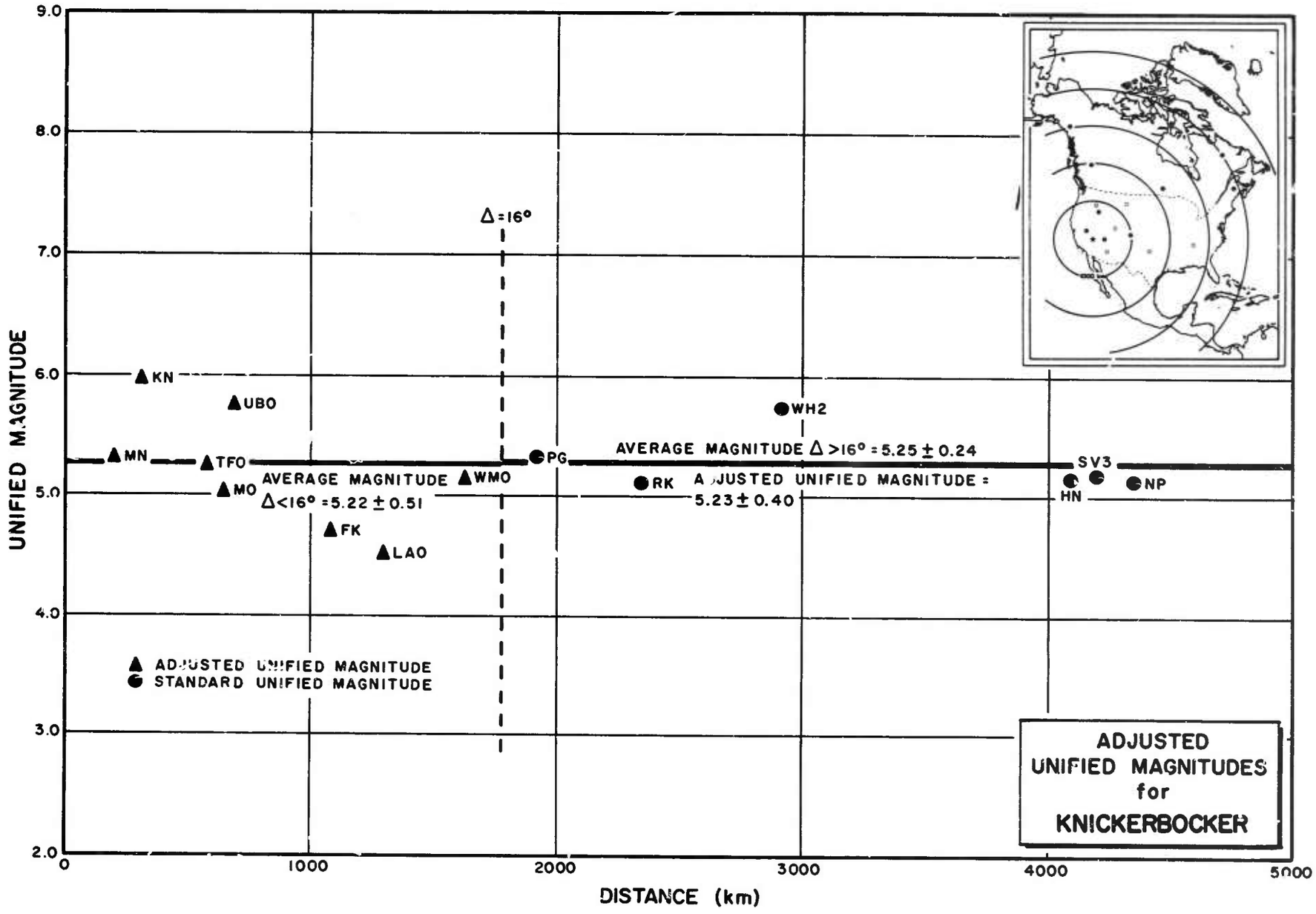

9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
UNIFIED MAGNITUDE
0
1000
2000
3000
4000
5000
DISTANCE (km)
Δ=16°
KN
UBO
WH2
MN
TFO
PG
SV3
MO
WMO
RK
HN
NP
FK
LAO
AVERAGE MAGNITUDE Δ>16° = 5.25 ± 0.24
AVERAGE MAGNITUDE Δ<16° = 5.22 ± 0.51
ADJUSTED UNIFIED MAGNITUDE = 5.23 ± 0.40
ADJUSTED UNIFIED MAGNITUDE
STANDARD UNIFIED MAGNITUDE
ADJUSTED
UNIFIED MAGNITUDES
for
KNICKERBOCKER

Figure 3

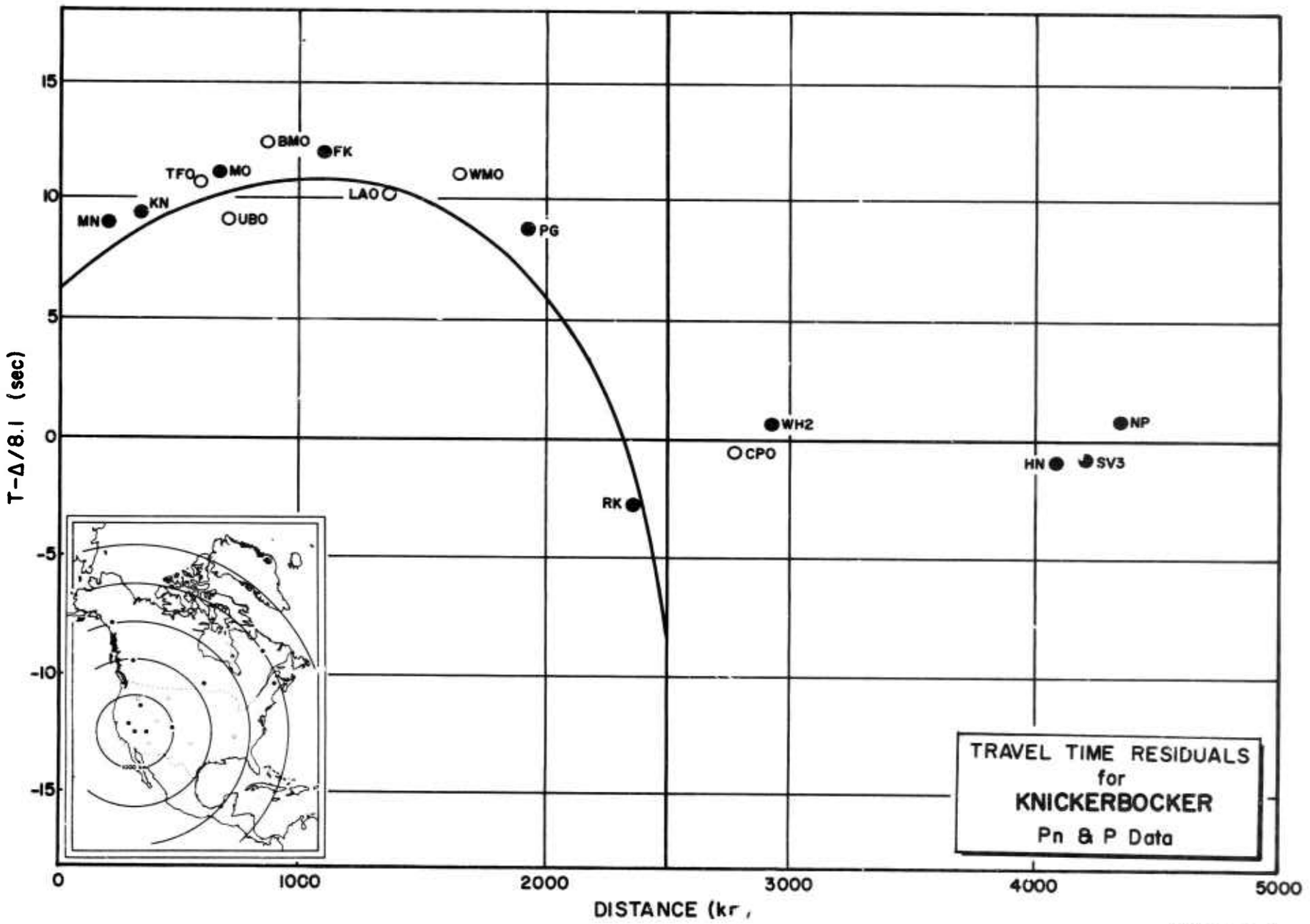

15
10
5
0
-5
-10
-15
T-Δ/8.1 (sec)
BMO
FK
TFO
MO
WMO
LAO
KN
MN
UBO
PG
WH2
NP
CPO
HN
SV3
RK
0
1000
2000
3000
4000
5000
DISTANCE (kr,
TRAVEL TIME RESIDUALS
for
KNICKERBOCKER
Pn & P Data

Figure 4

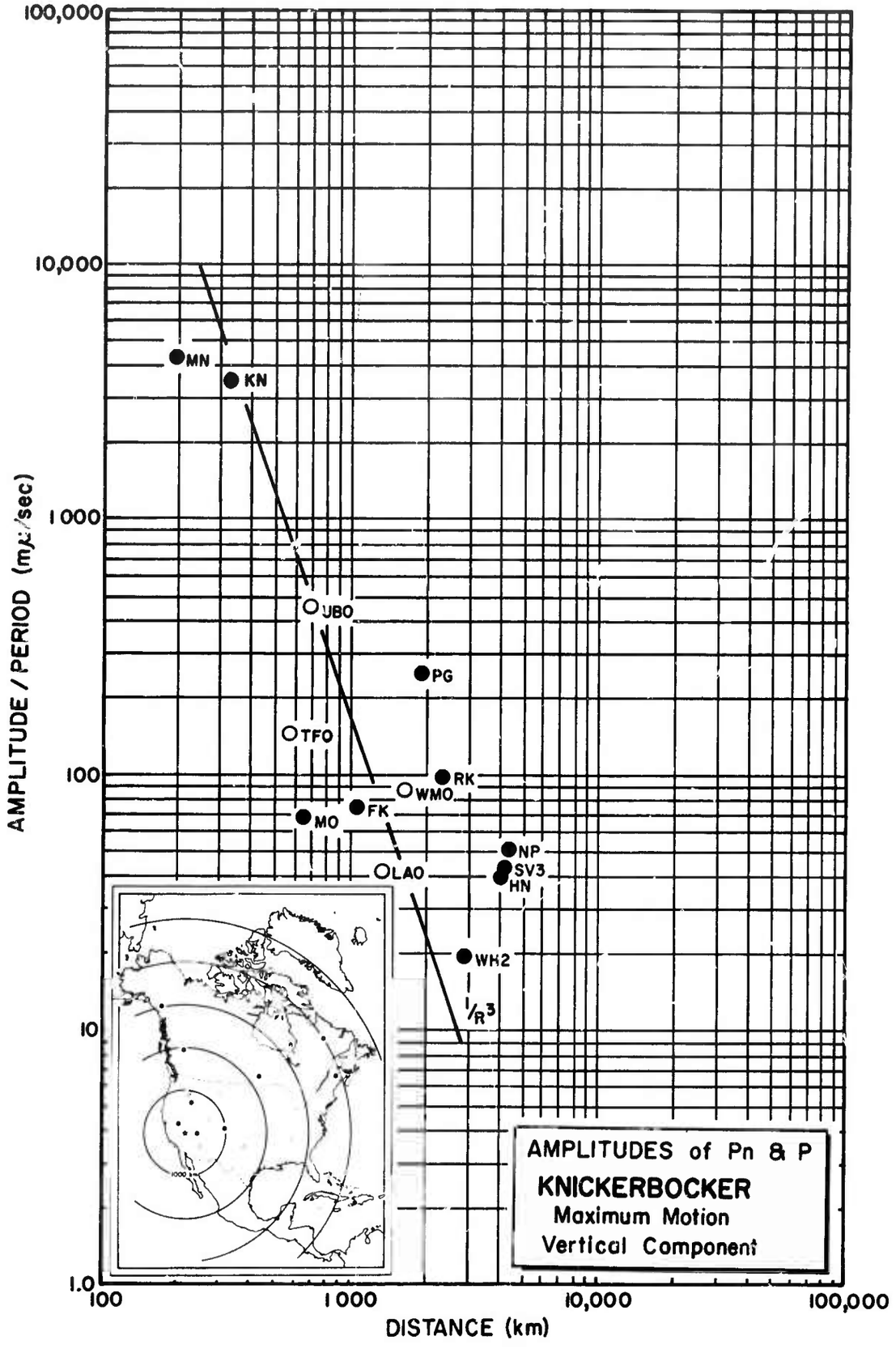

100,000
10,000
1 000
100
10
1.0
AMPLITUDE / PERIOD (mμ/sec)
MN
KN
UBO
PG
TFO
RK
WMO
MO
FK
NP
SV3
HN
LAO
WH2
1/R3
100
1 000
10,000
100,000
DISTANCE (km)
AMPLITUDES of Pn & P
KNICKERBOCKER
Maximum Motion
Vertical Component

Figure 5

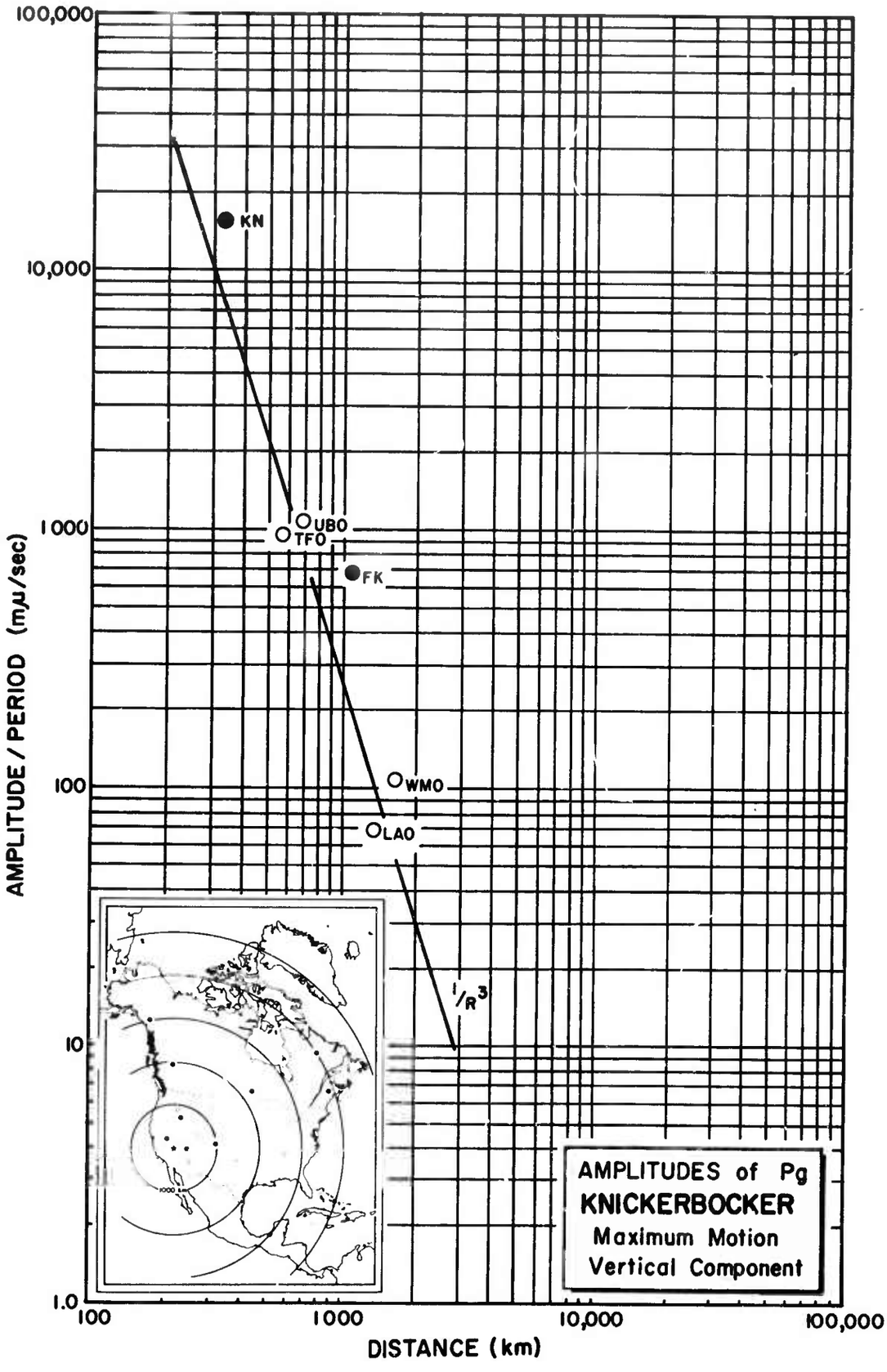
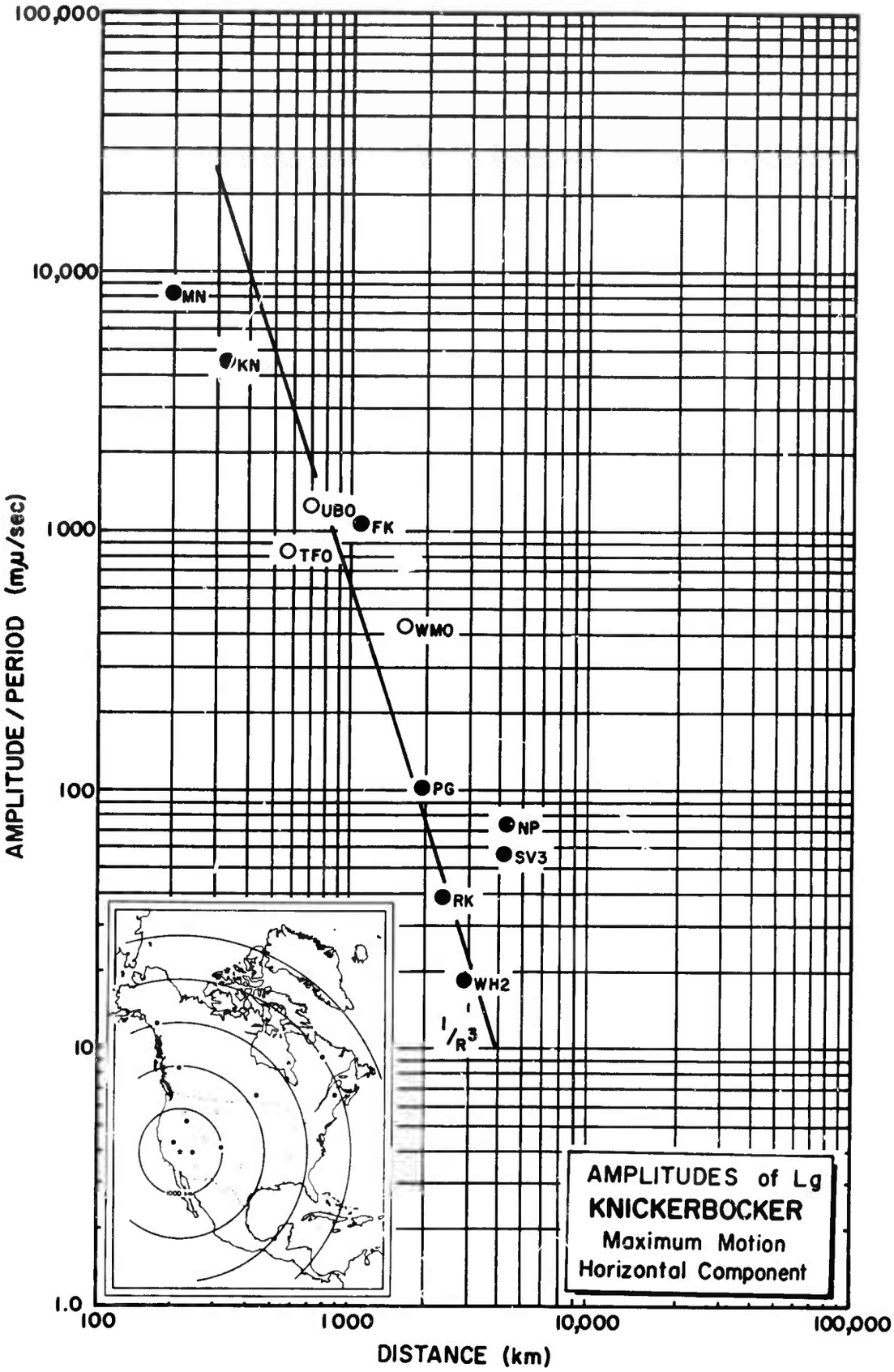

100,000
10,000
1000
100
10
1.0
AMPLITUDE / PERIOD (mμ/sec)
KN
UBO
TFO
FK
WMO
LAO
1/R3
100
1000
10,000
100,000
DISTANCE (km)
AMPLITUDES of Pg
KNICKERBOCKER
Maximum Motion
Vertical Component

Figure 6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10,000
1000
100
10
1.0
AMPLITUDE / PERIOD (mμ/sec)
MN
KN
UBO
FK
TFO
WMO
PG
NP
SV3
RK
WH2
1/R3
100
1000
10,000
100,000
DISTANCE (km)
AMPLITUDES of Lg
KNICKERBOCKER
Maximum Motion
Horizontal Component

Figure 7

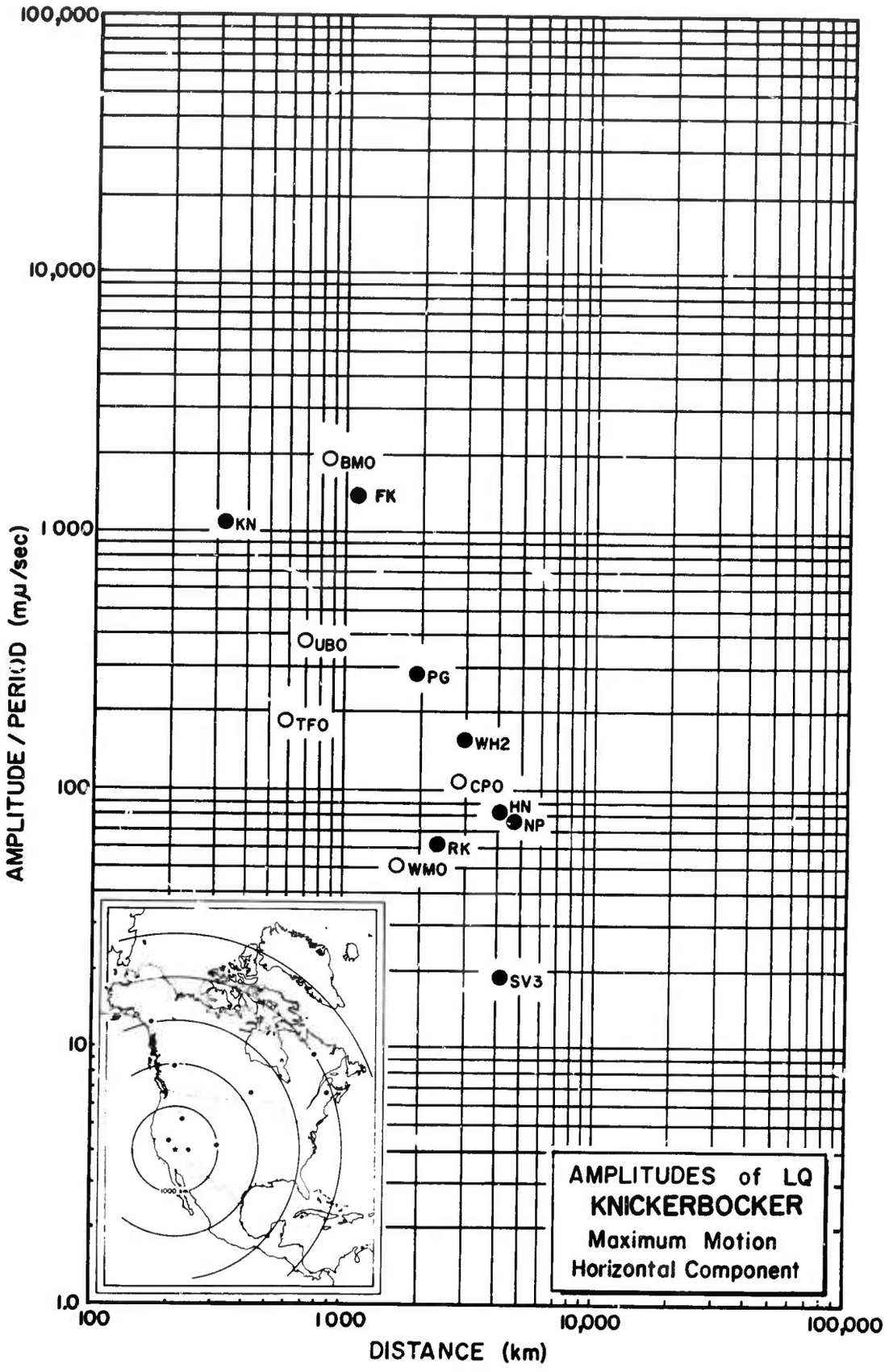

100,000
10,000
1 000
100
10
1.0
AMPLITUDE / PERIOD (mμ/sec)
BMO
FK
KN
UBO
PG
TFO
WH2
CPO
HN
NP
RK
WMO
SV3
100
1000
10,000
100,000
DISTANCE (km)
AMPLITUDES of LQ
KNICKERBOCKER
Maximum Motion
Horizontal Component

Figure 8

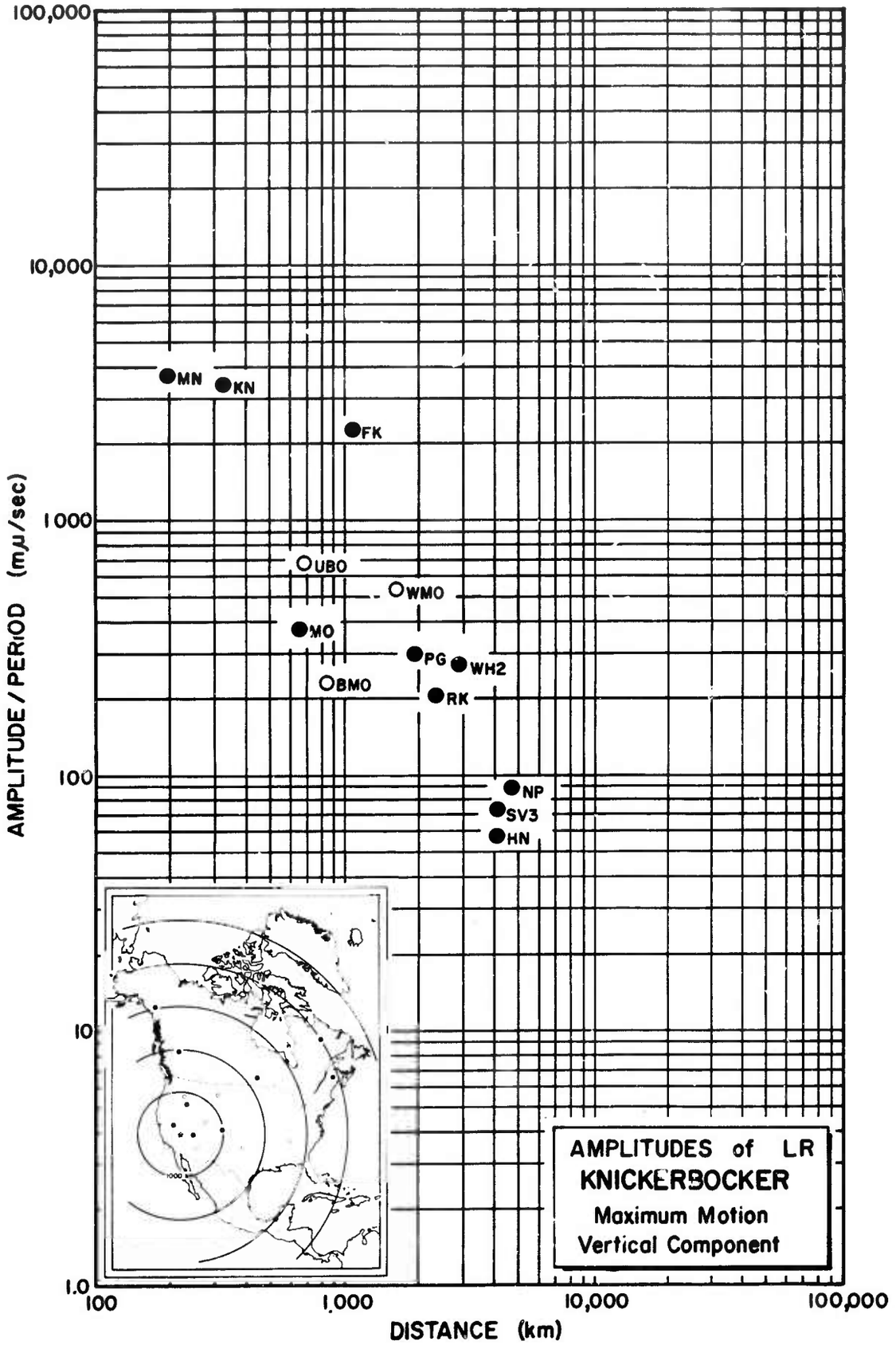

100,000
10,000
1 000
100
10
1.0
AMPLITUDE / PERIOD (mμ/sec)
MN
KN
FK
UBO
WMO
MO
PG
WH2
BMO
RK
NP
SV3
HN
100
1,000
10,000
100,000
DISTANCE (km)
AMPLITUDES of LR
KNICKERBOCKER
Maximum Motion
Vertical Component

Figure 9

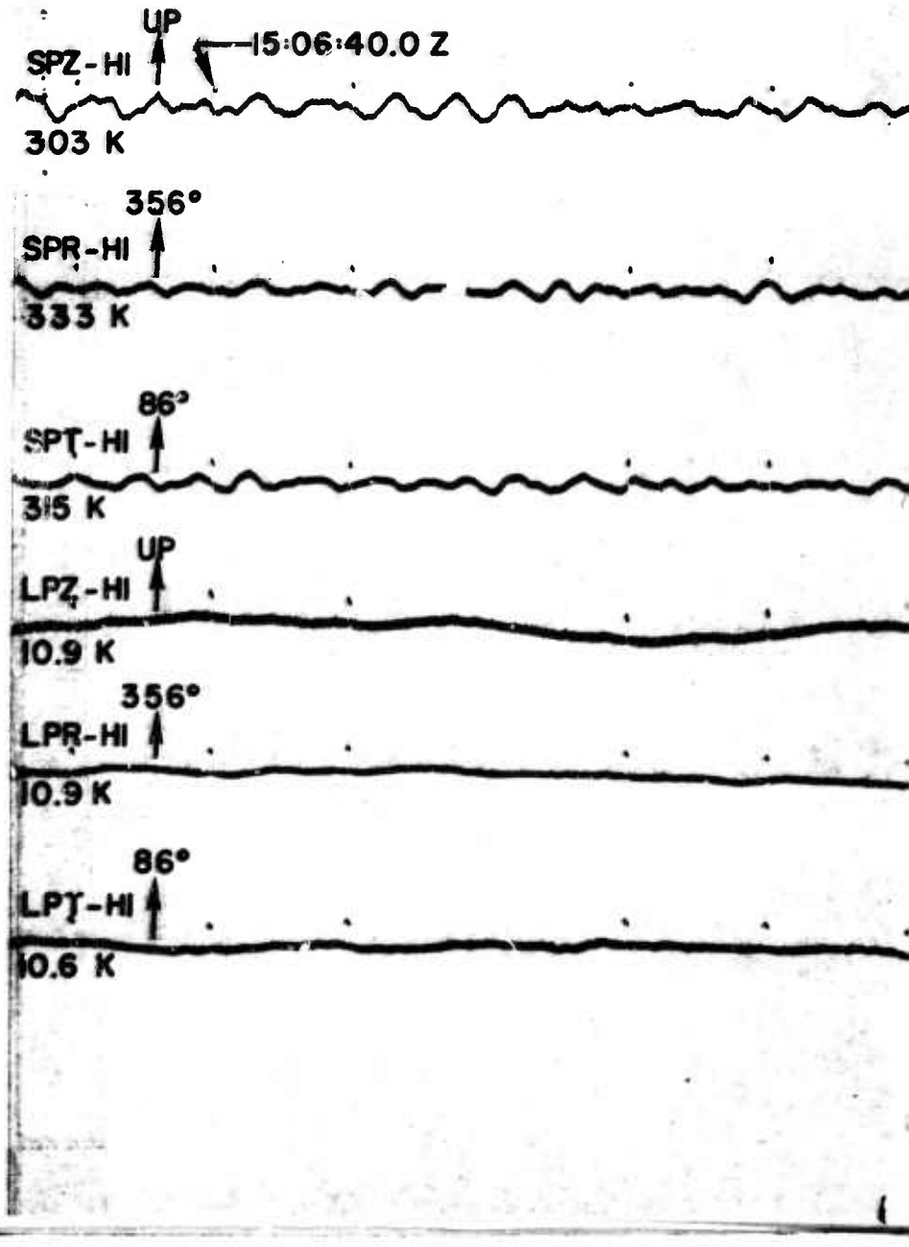
KNICKERBOCKER

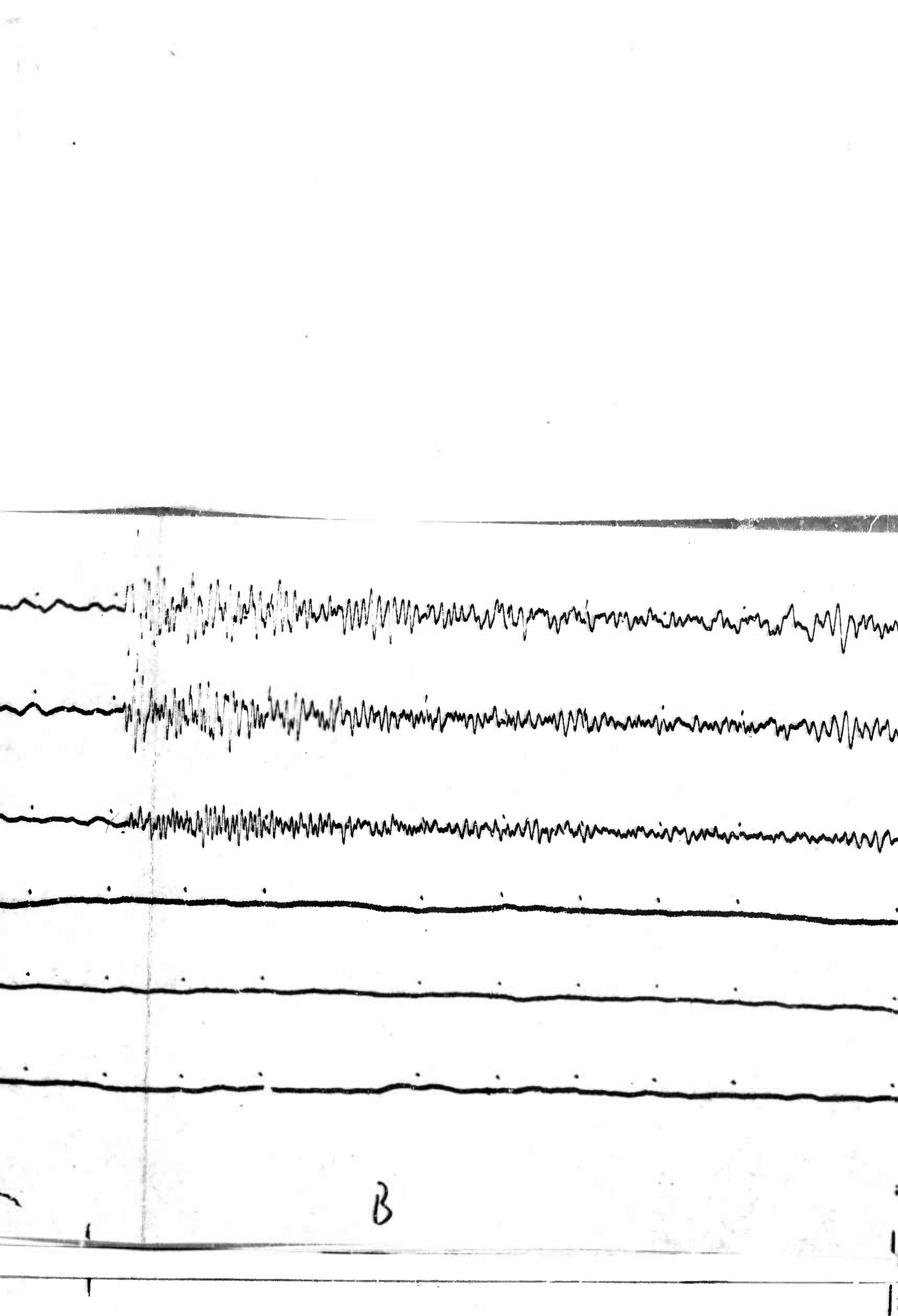
NP-NT

MOULD BAY, NORTHWEST TERRITORY, CANADA

26 MAY 1967

Δ= 4350 km

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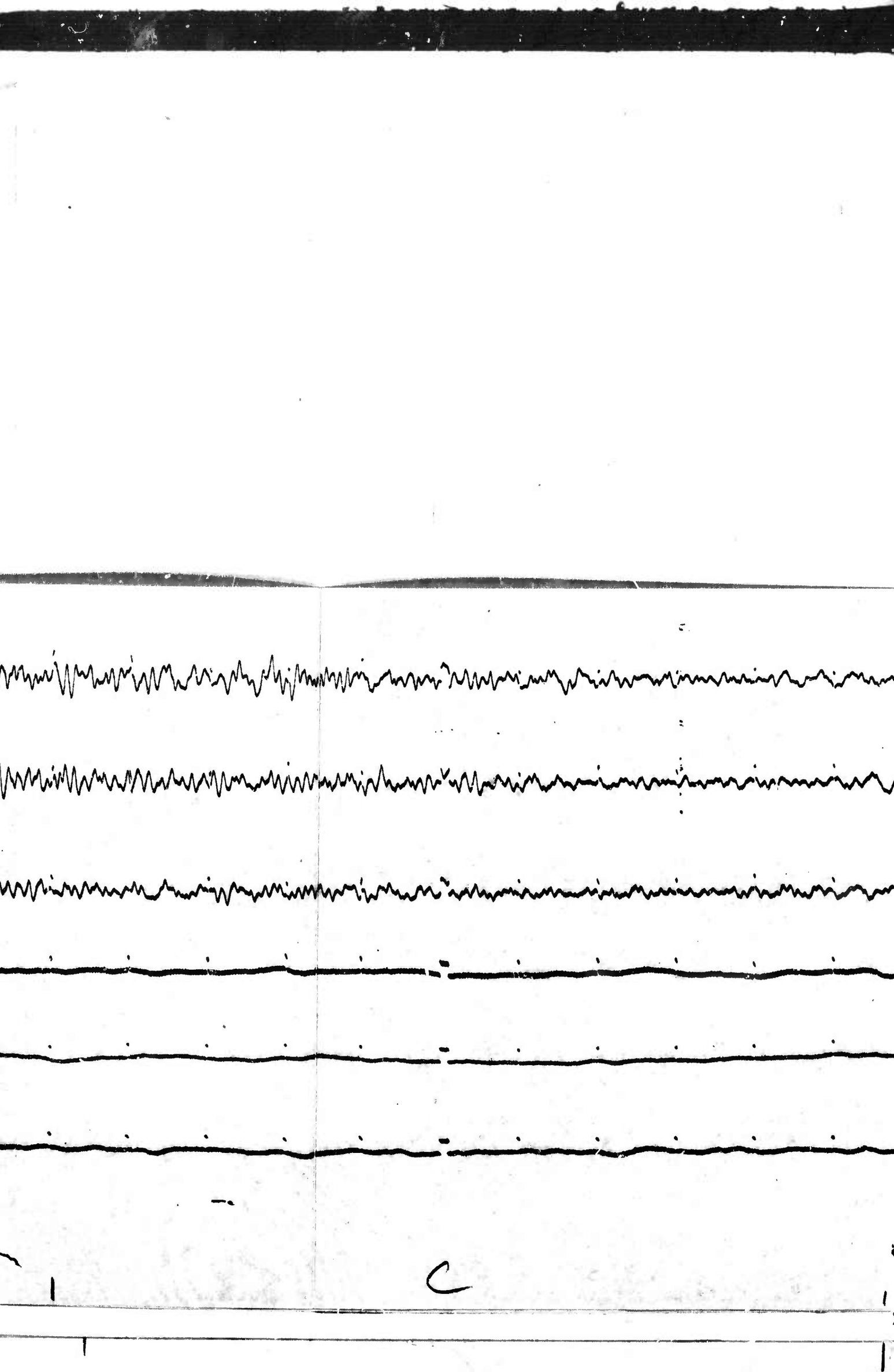

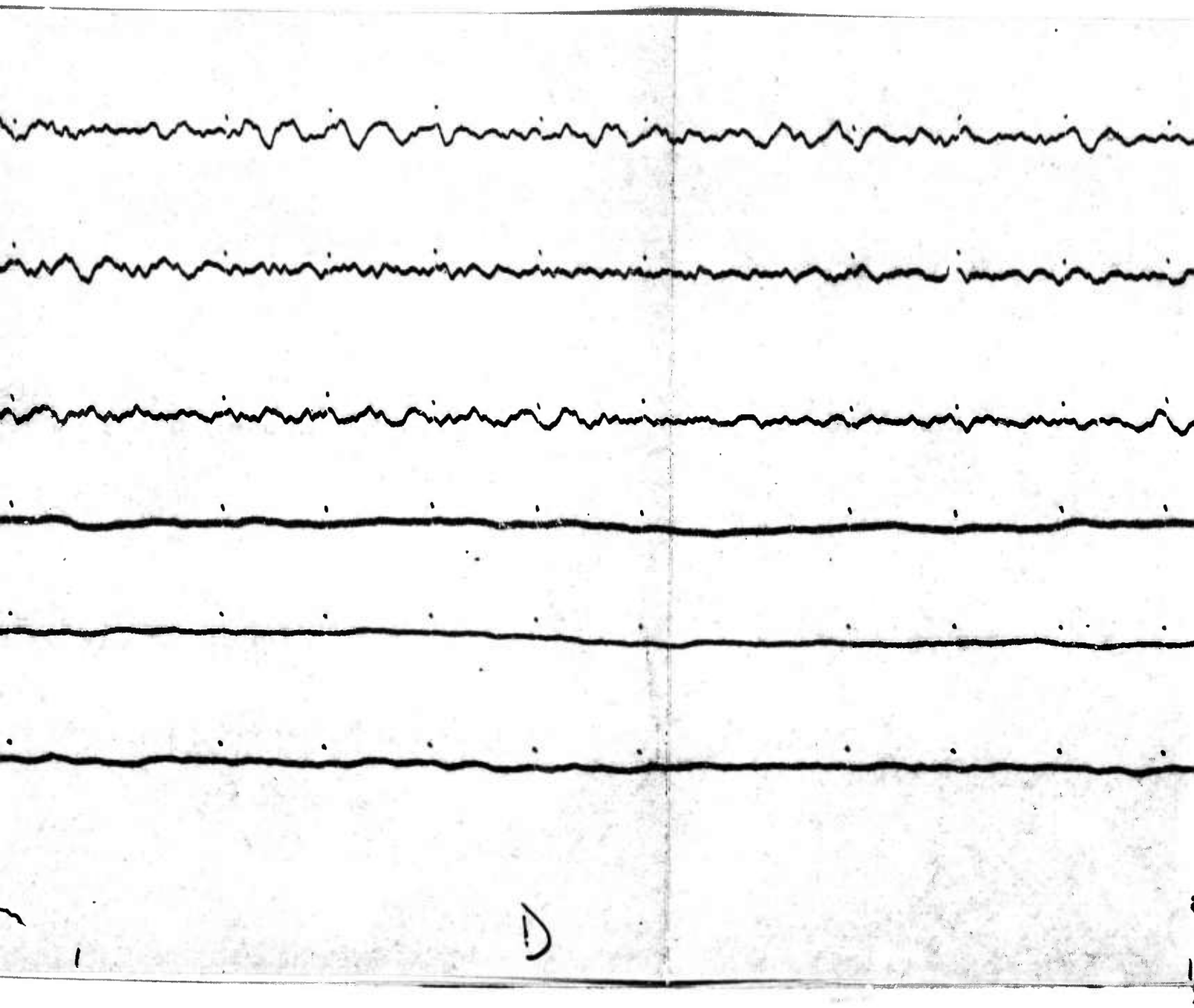

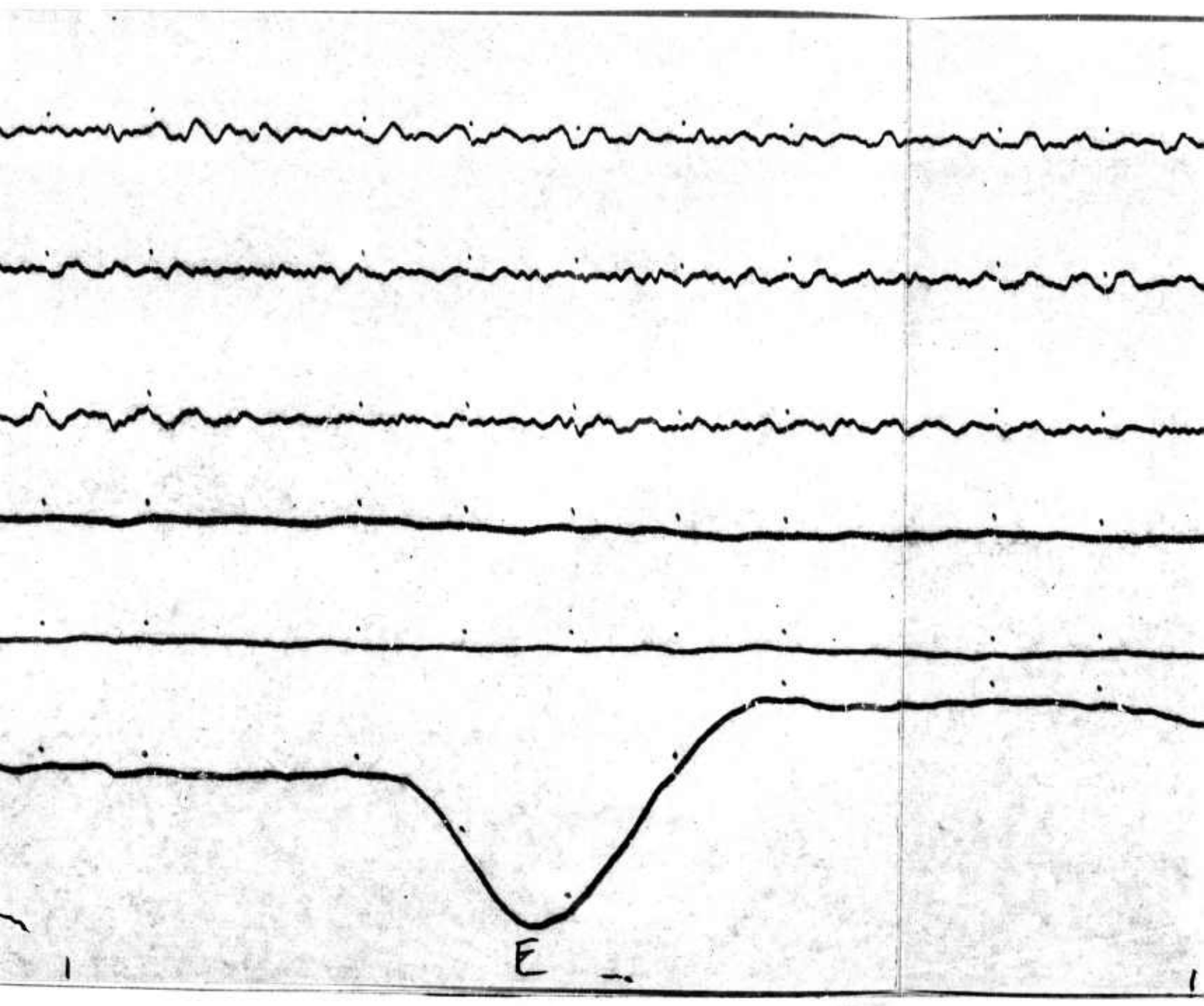
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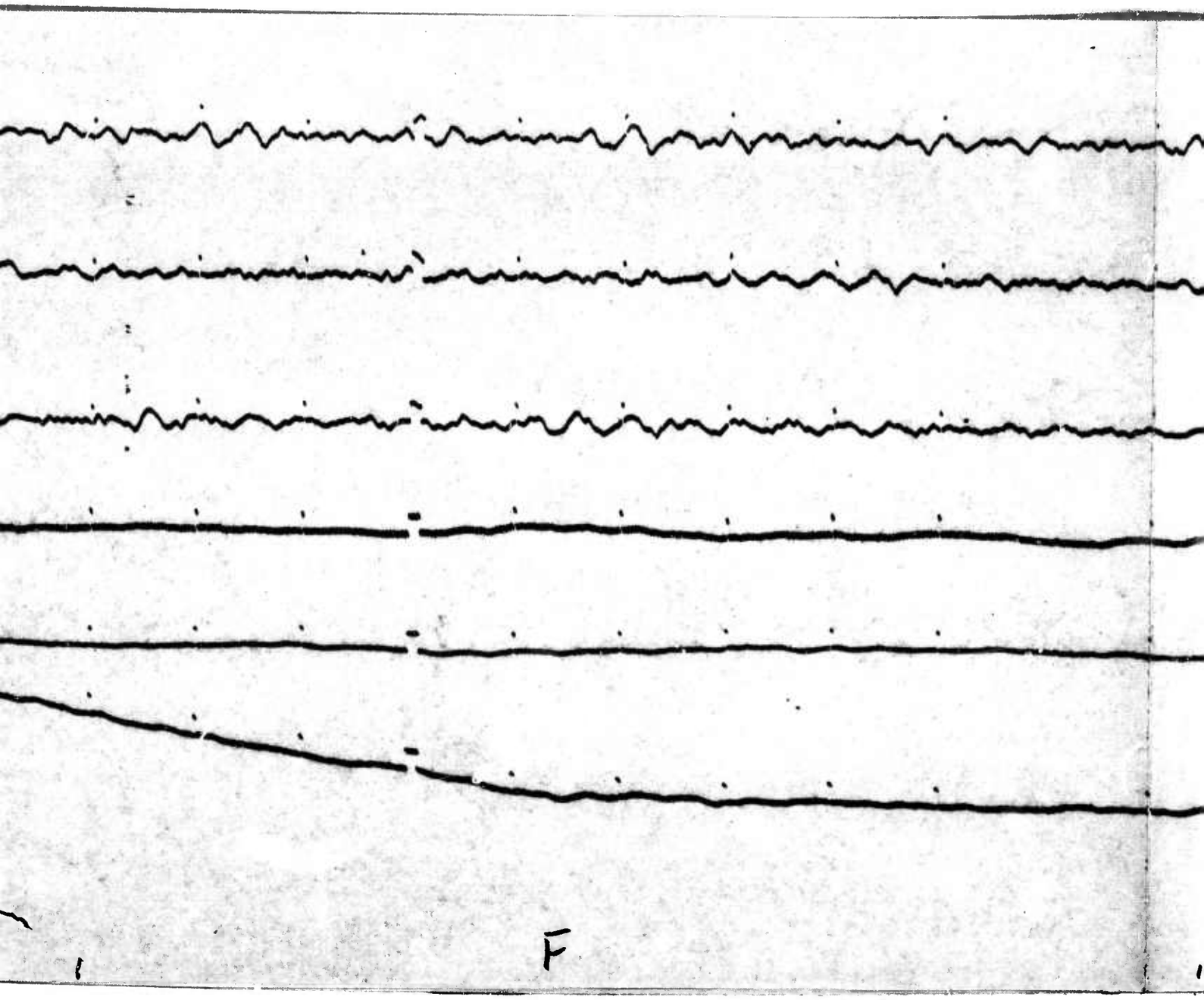
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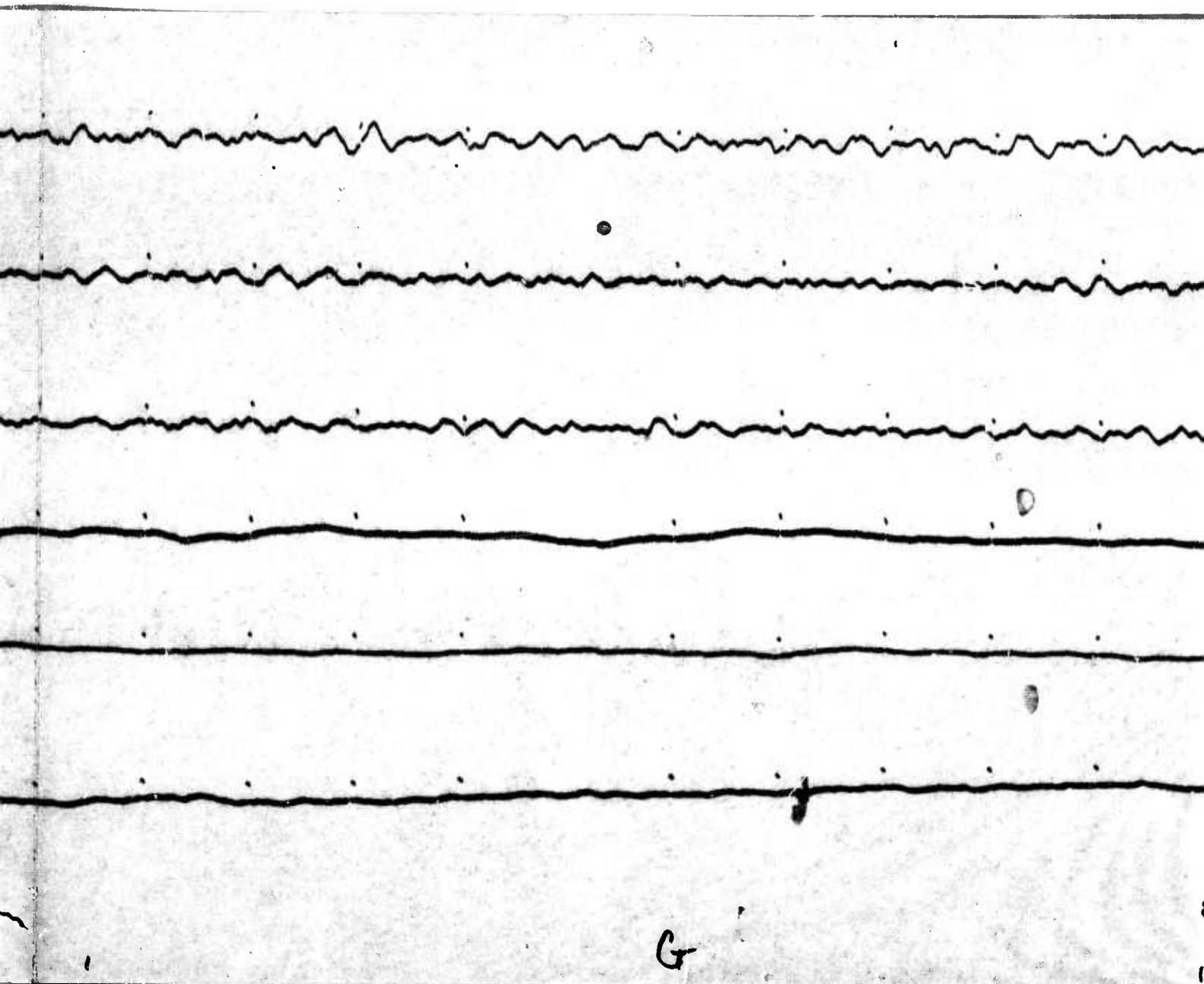
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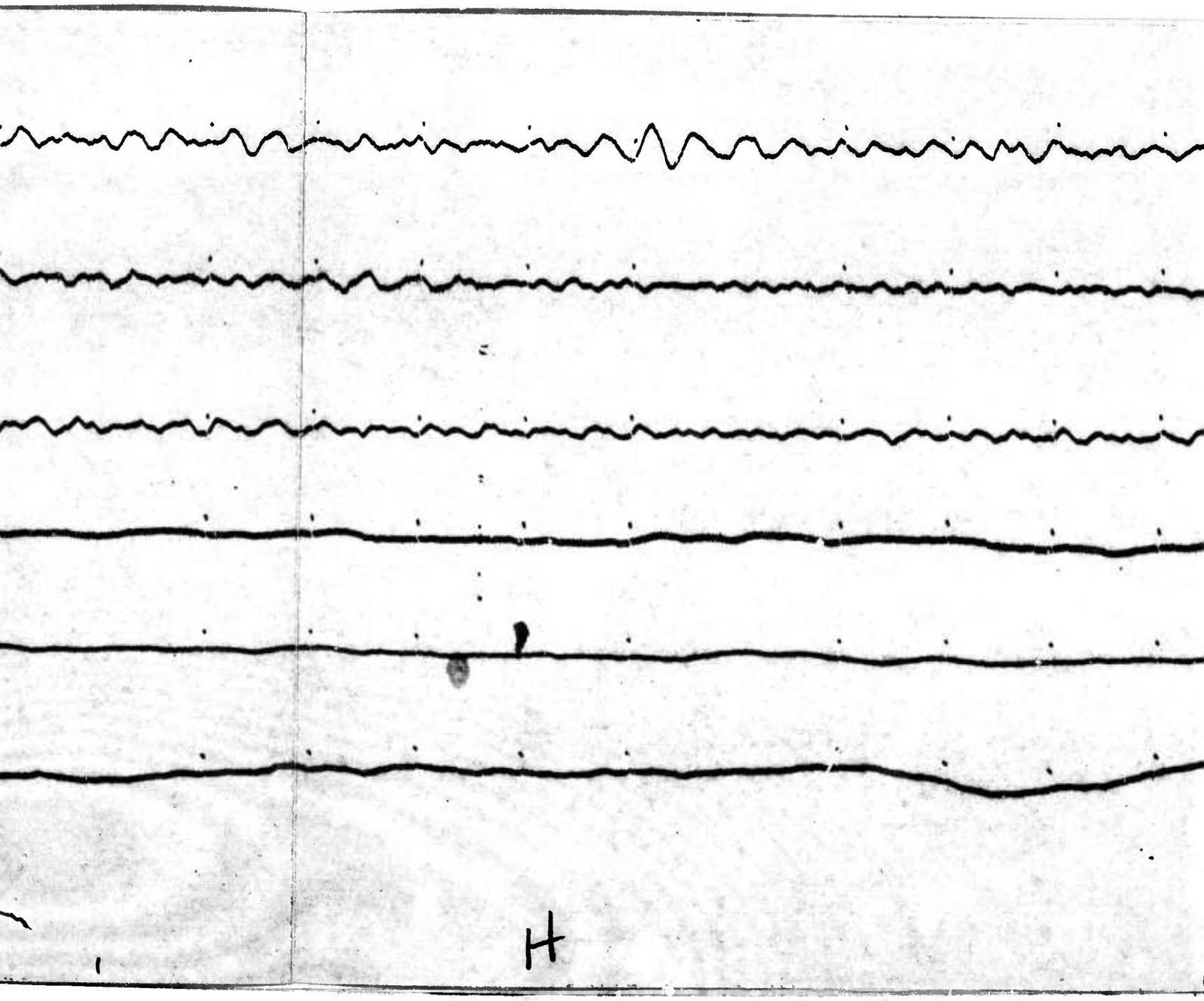
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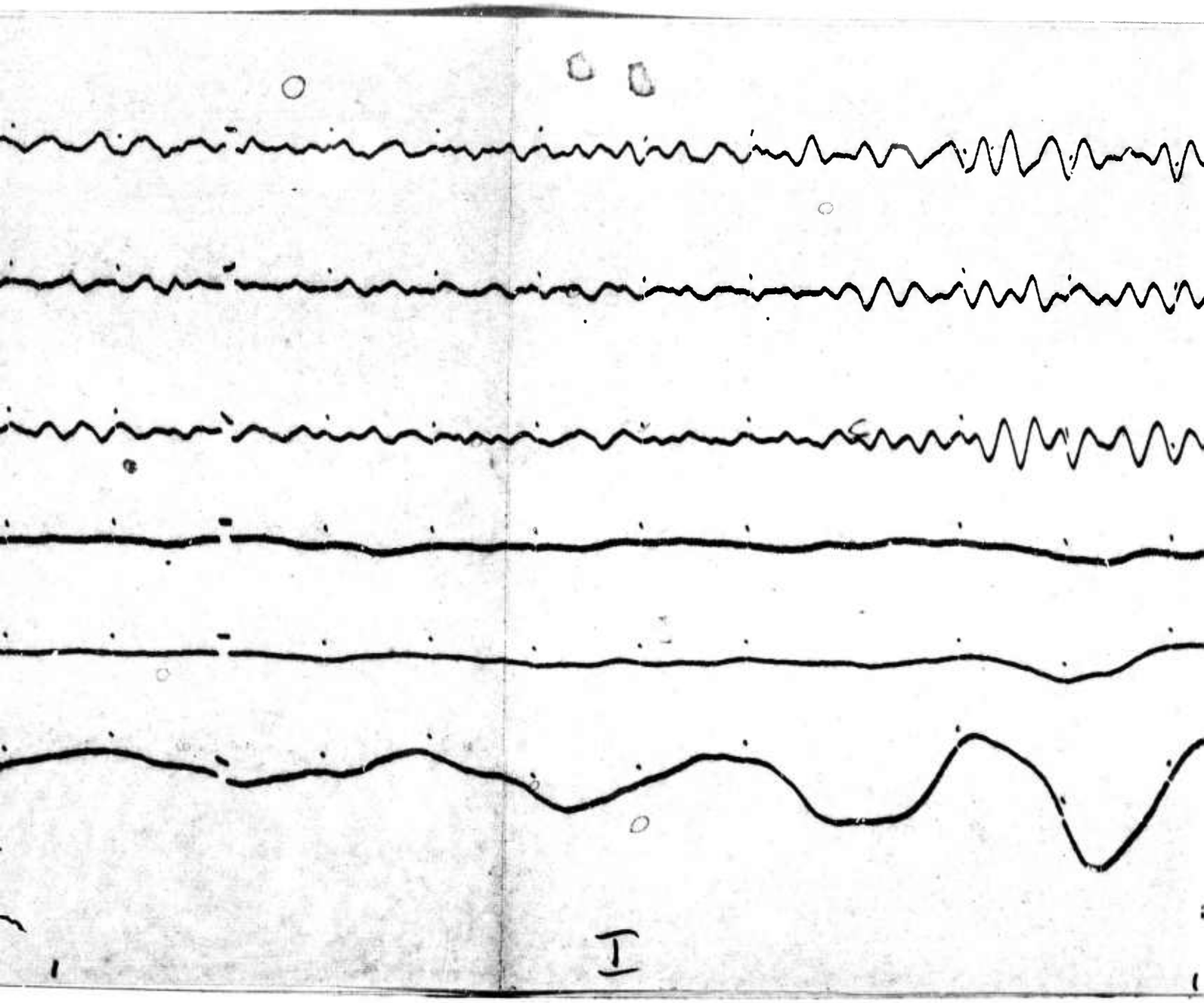
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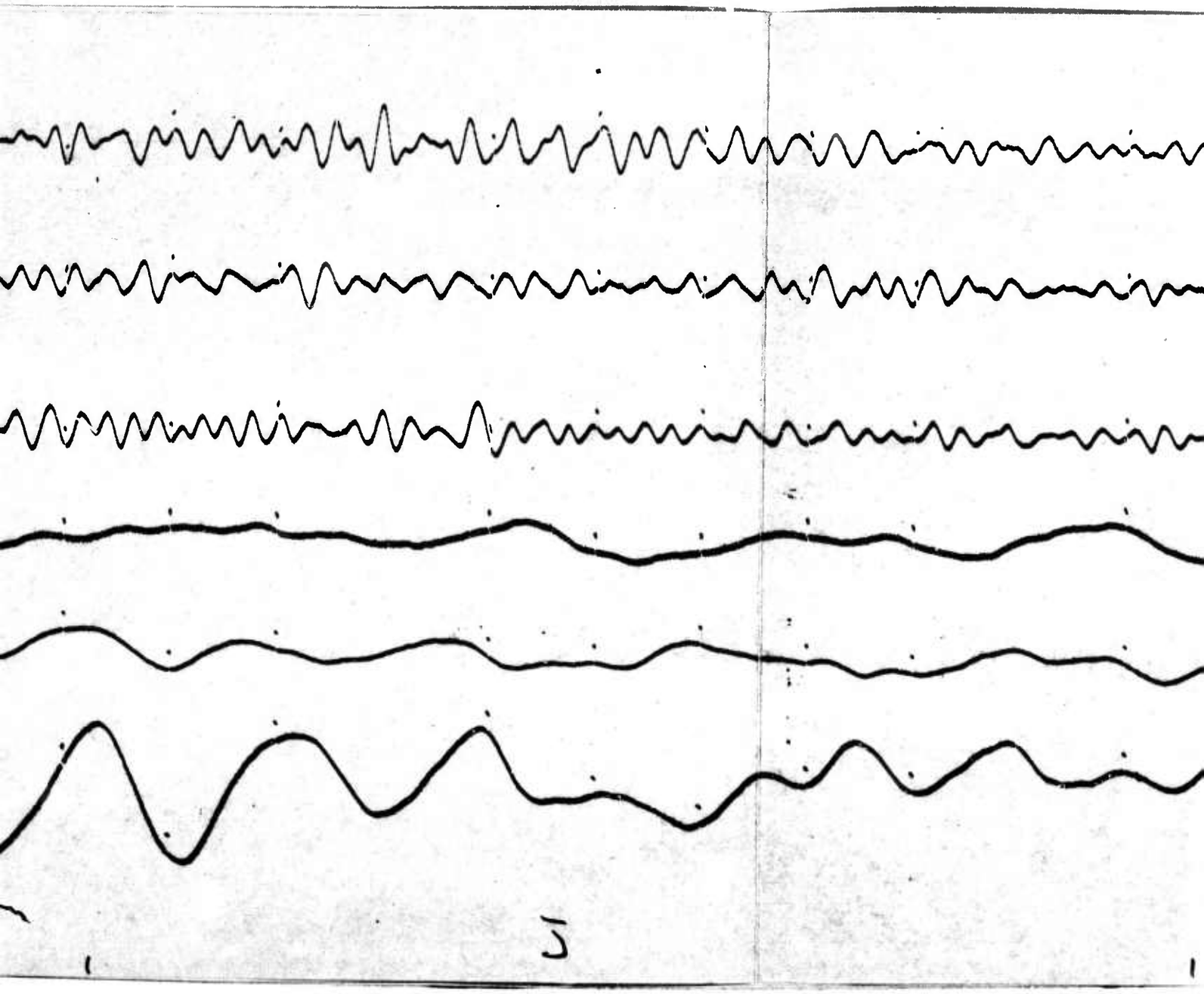
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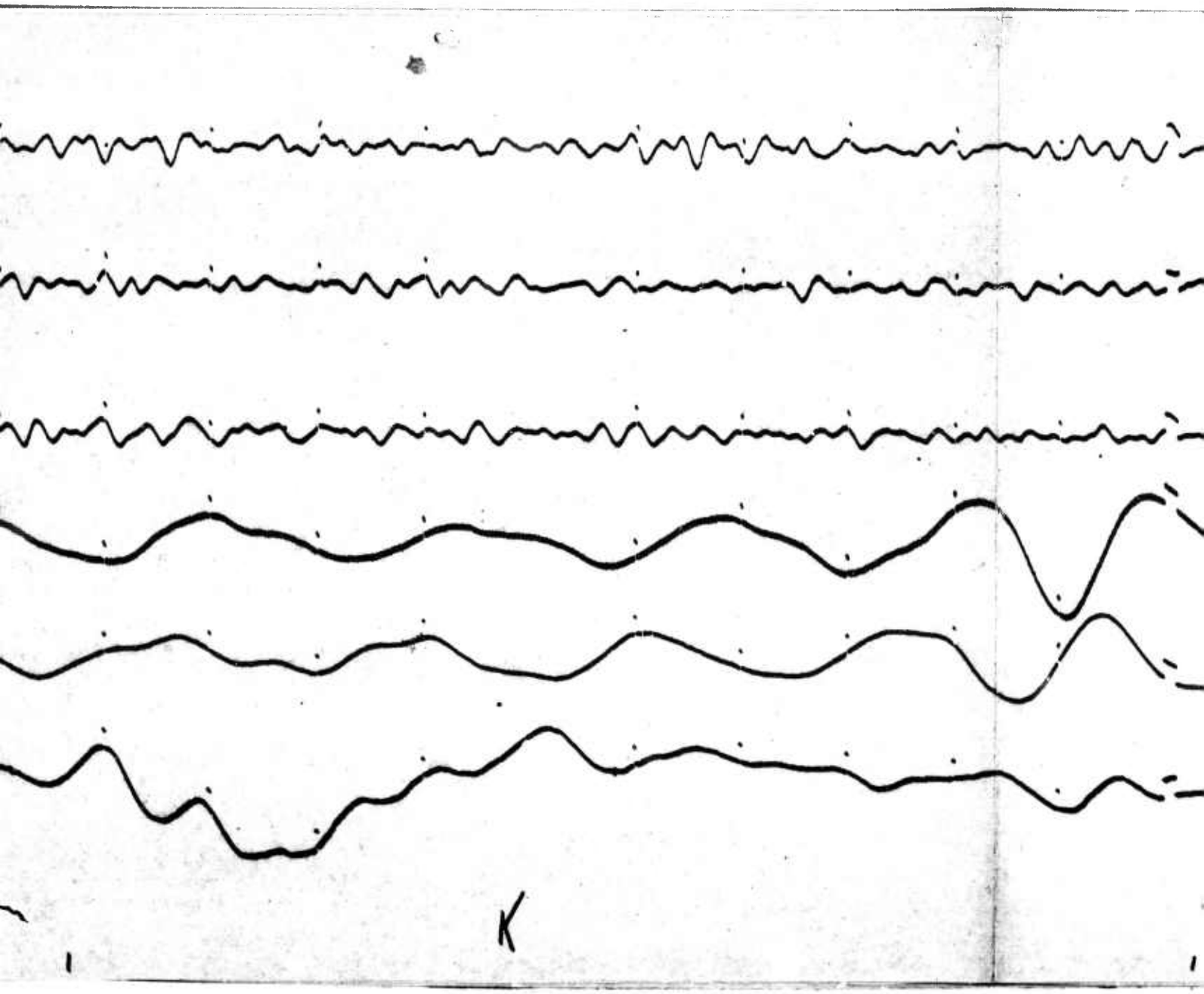
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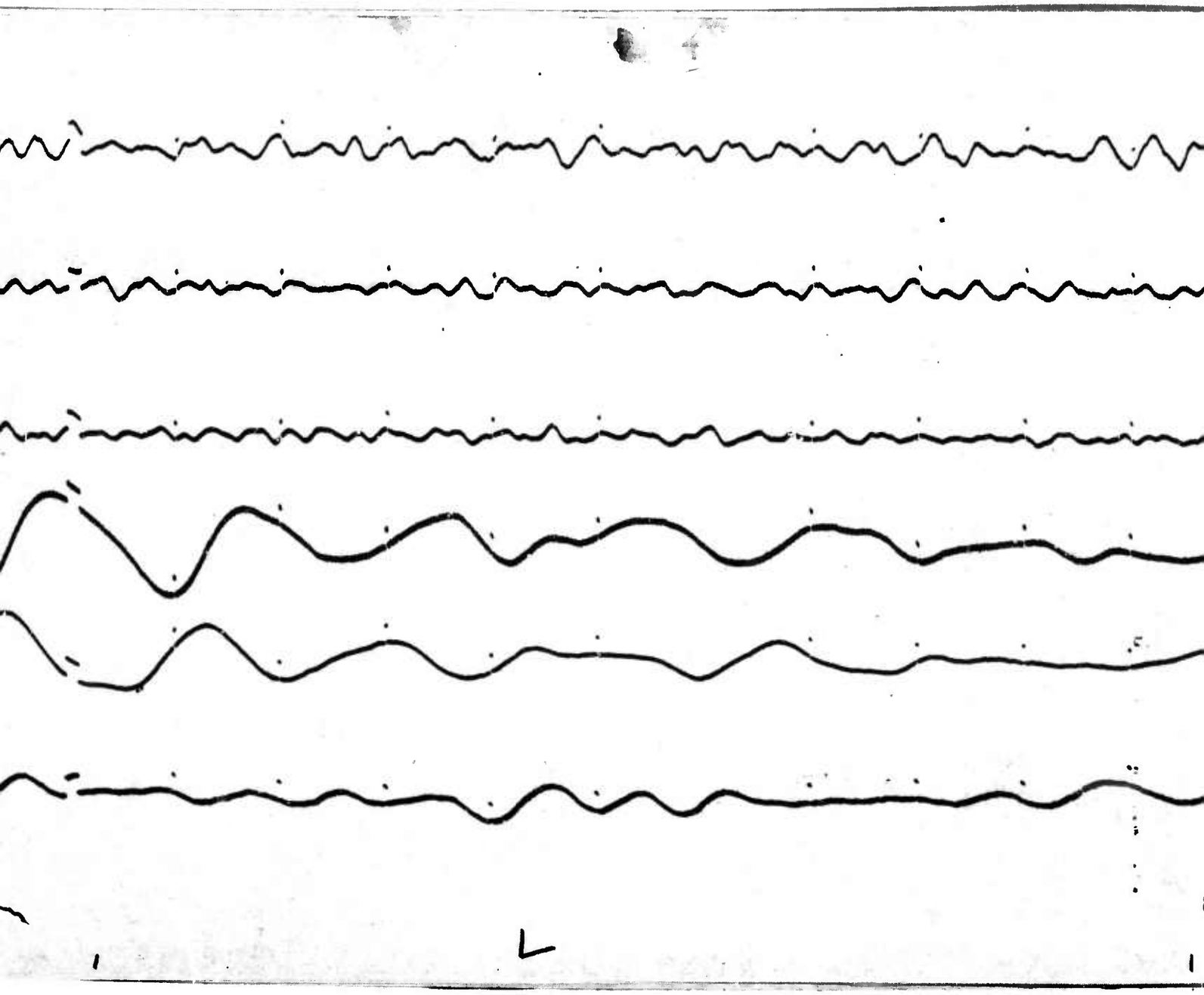

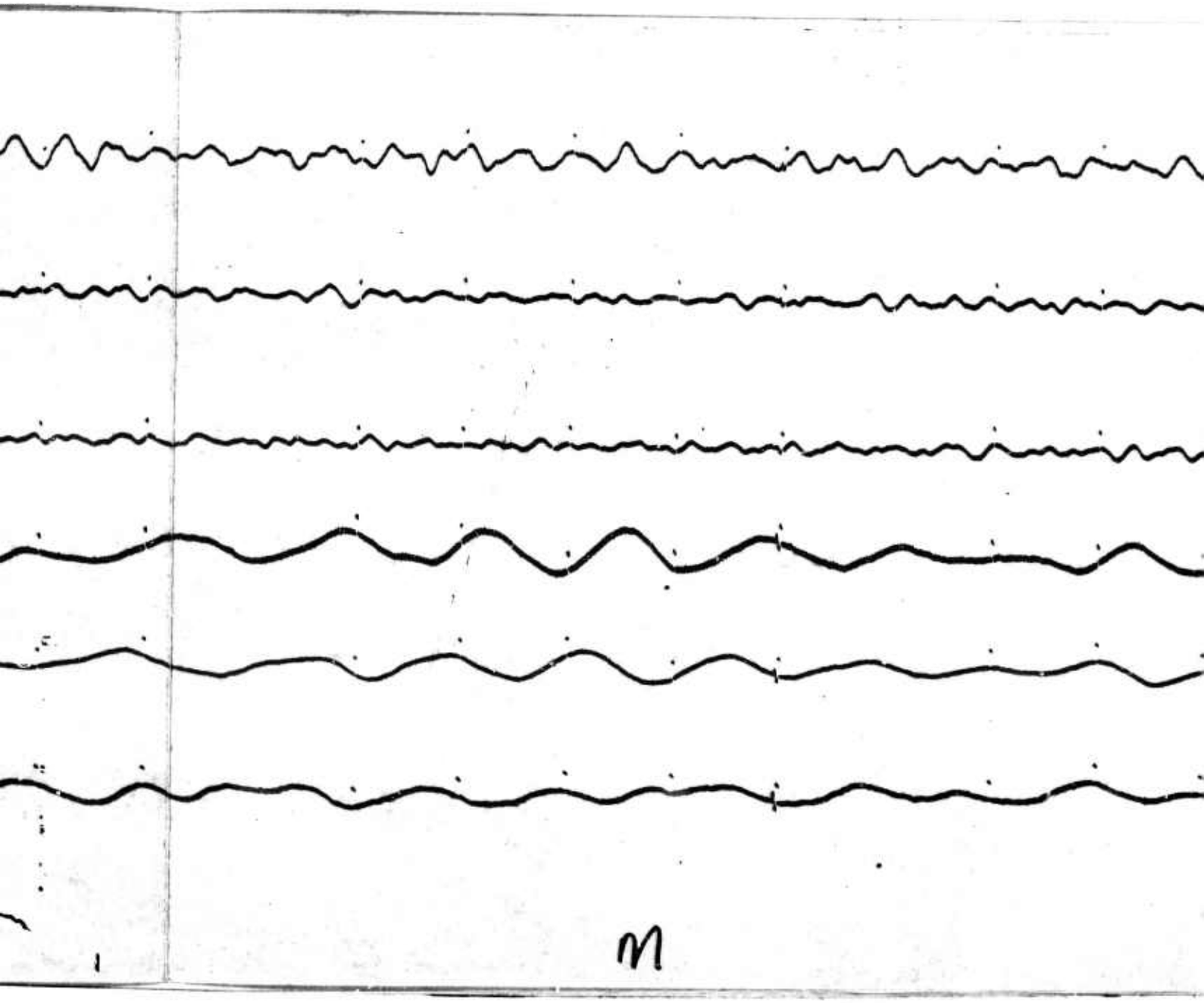
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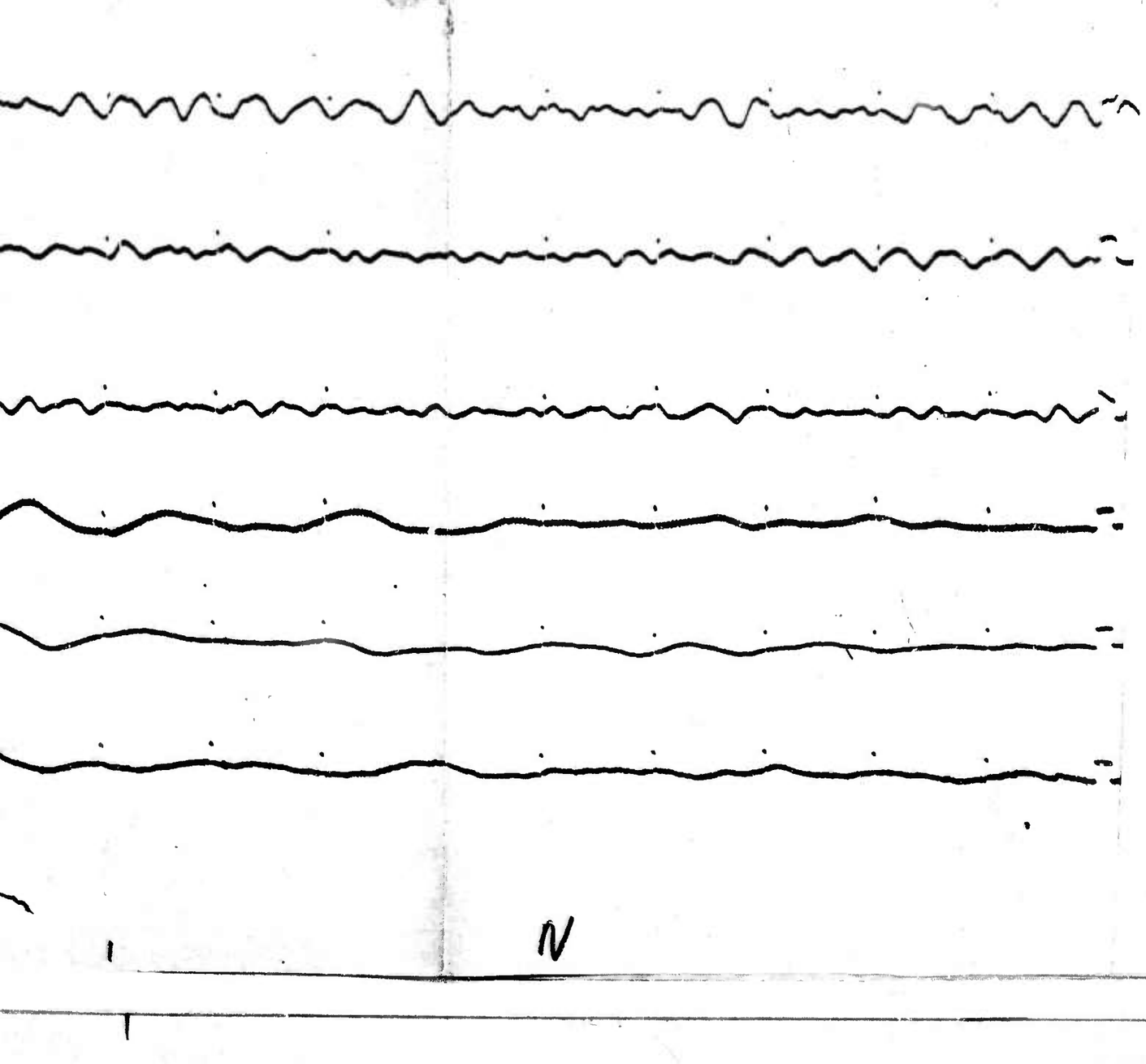
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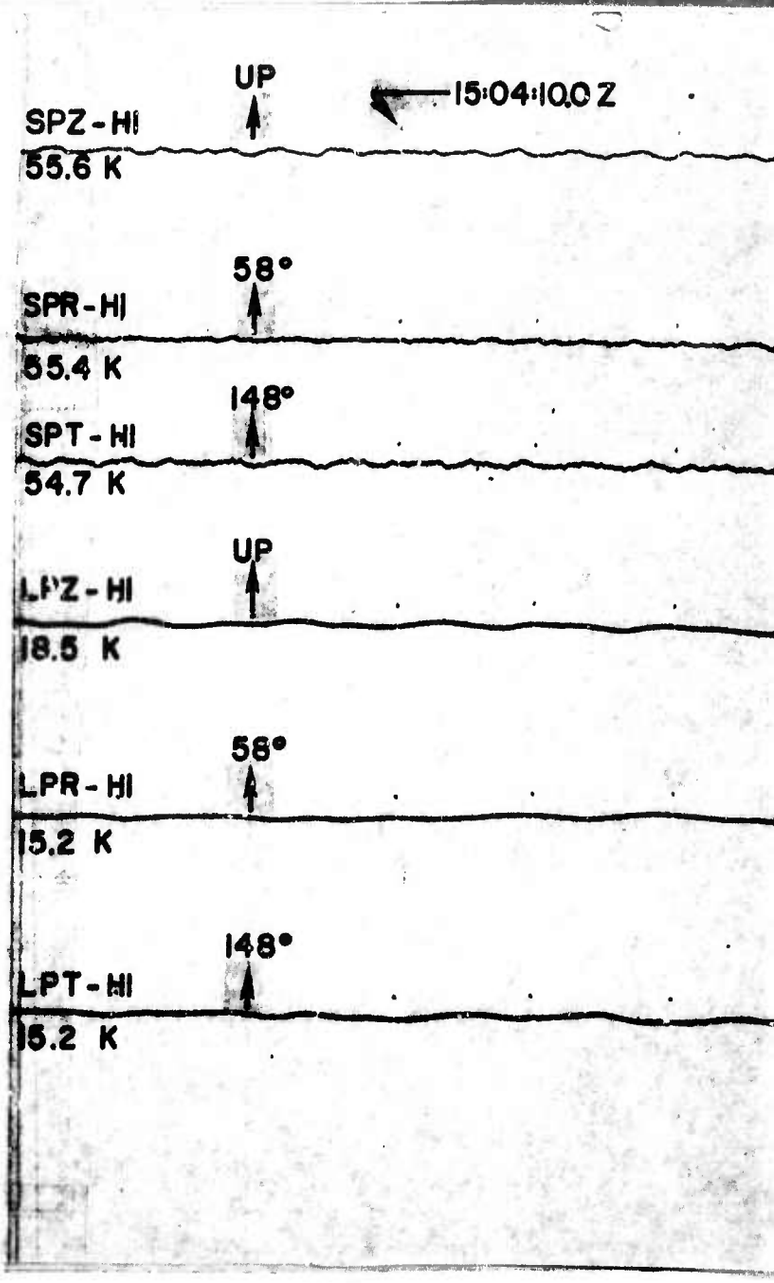
KNICKERBOCKER

RK-ON

RED LAKE, ONTARIO, CANADA

26 MAY 1967

Δ = 2355 km



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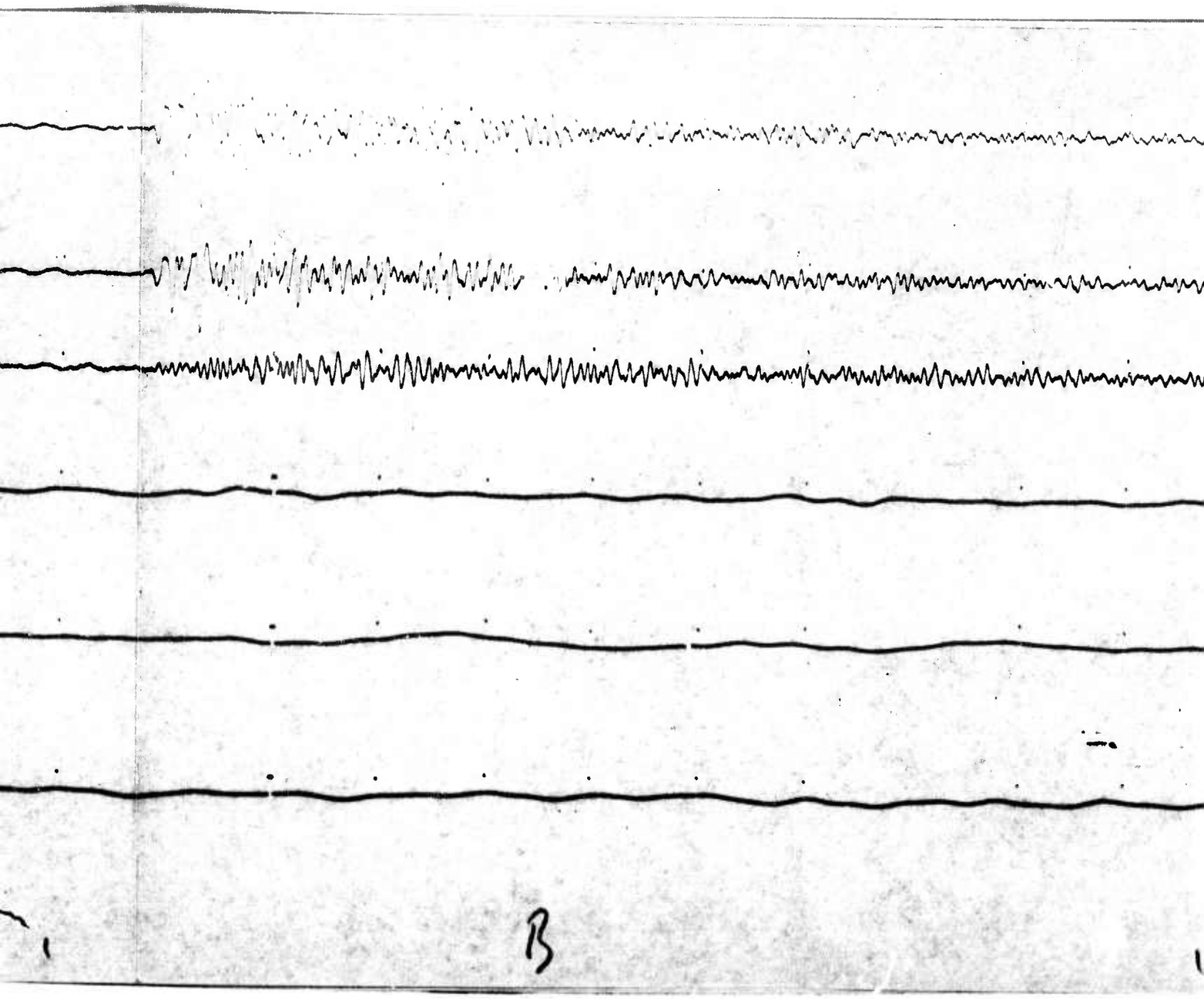
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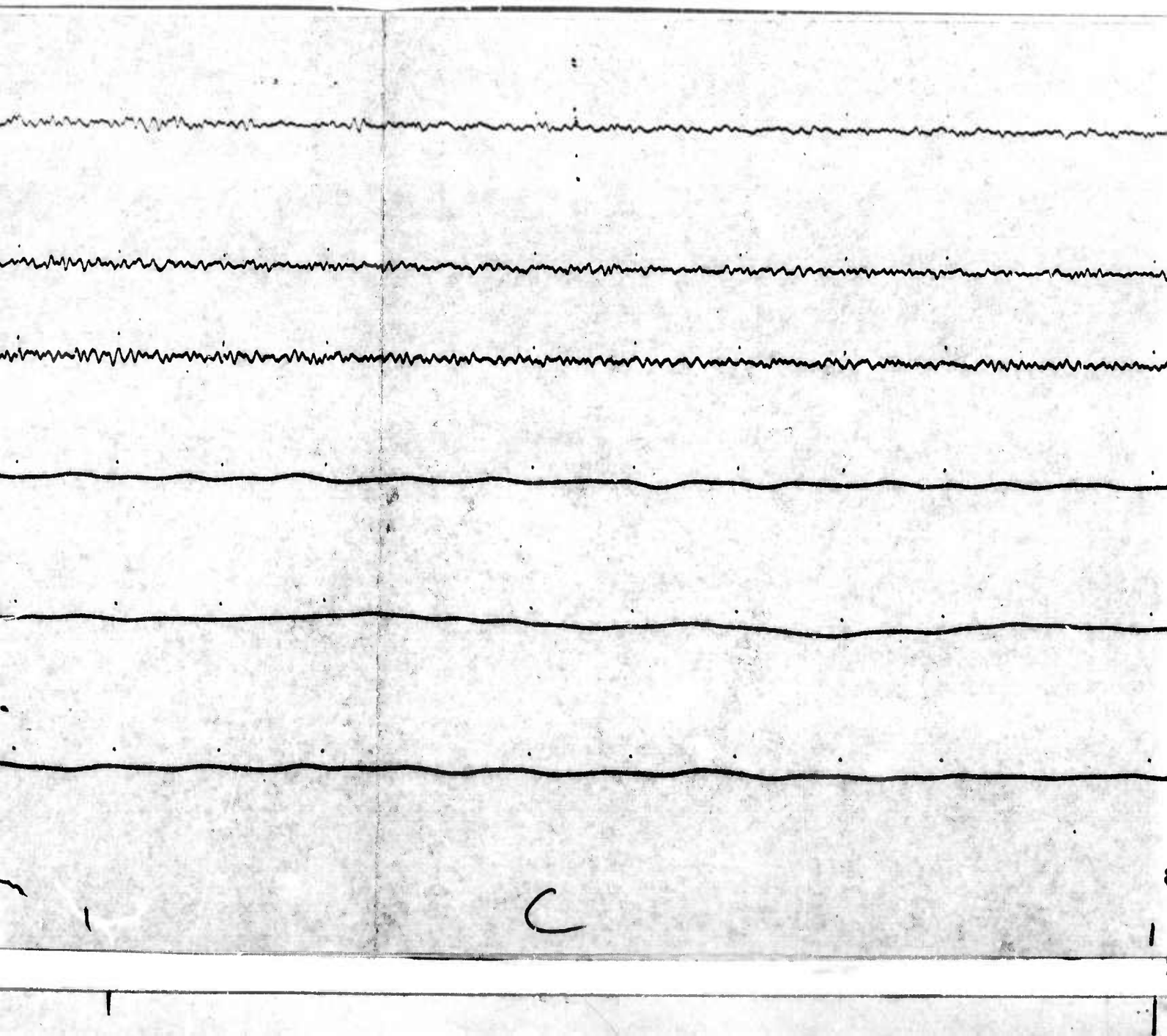

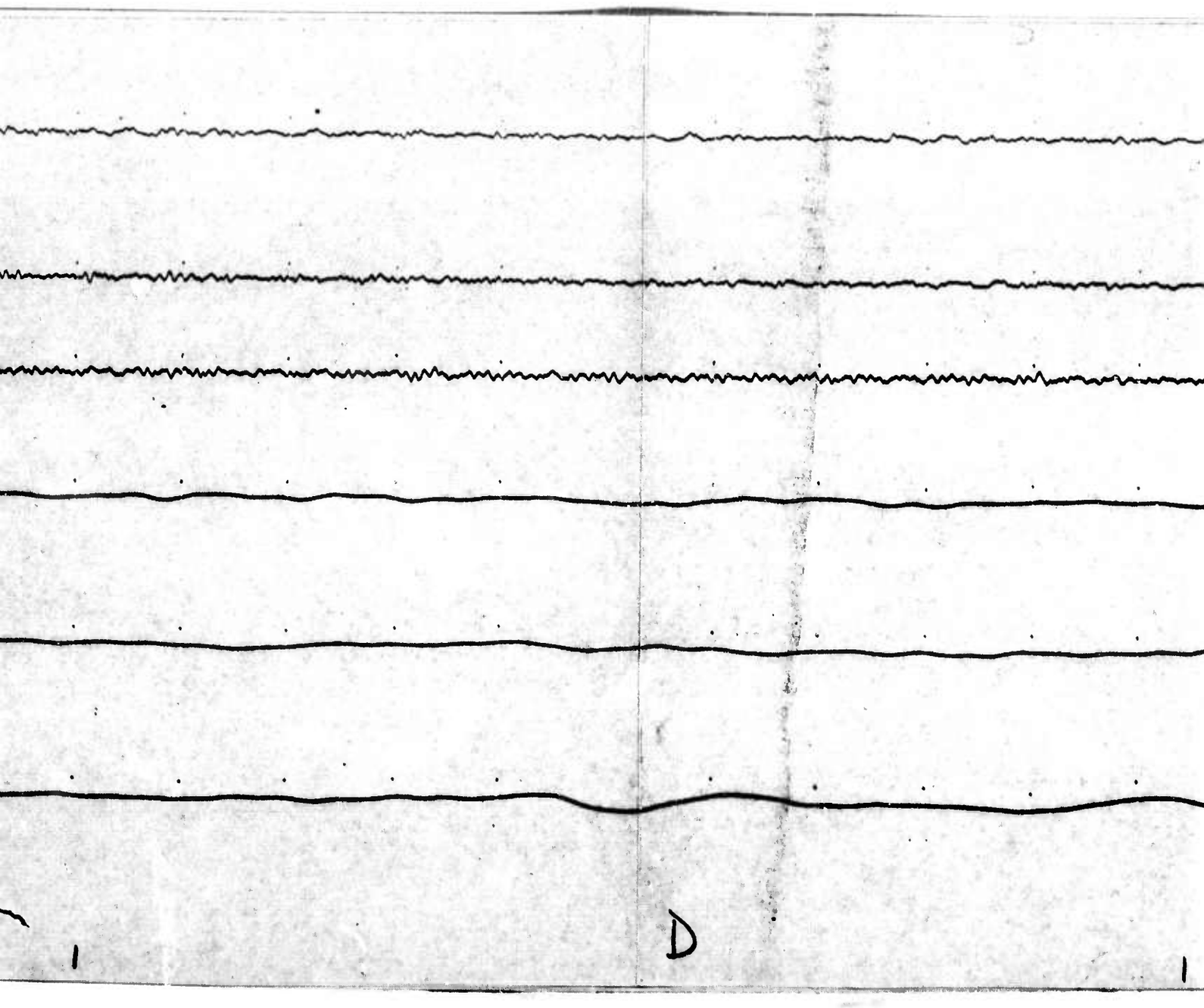
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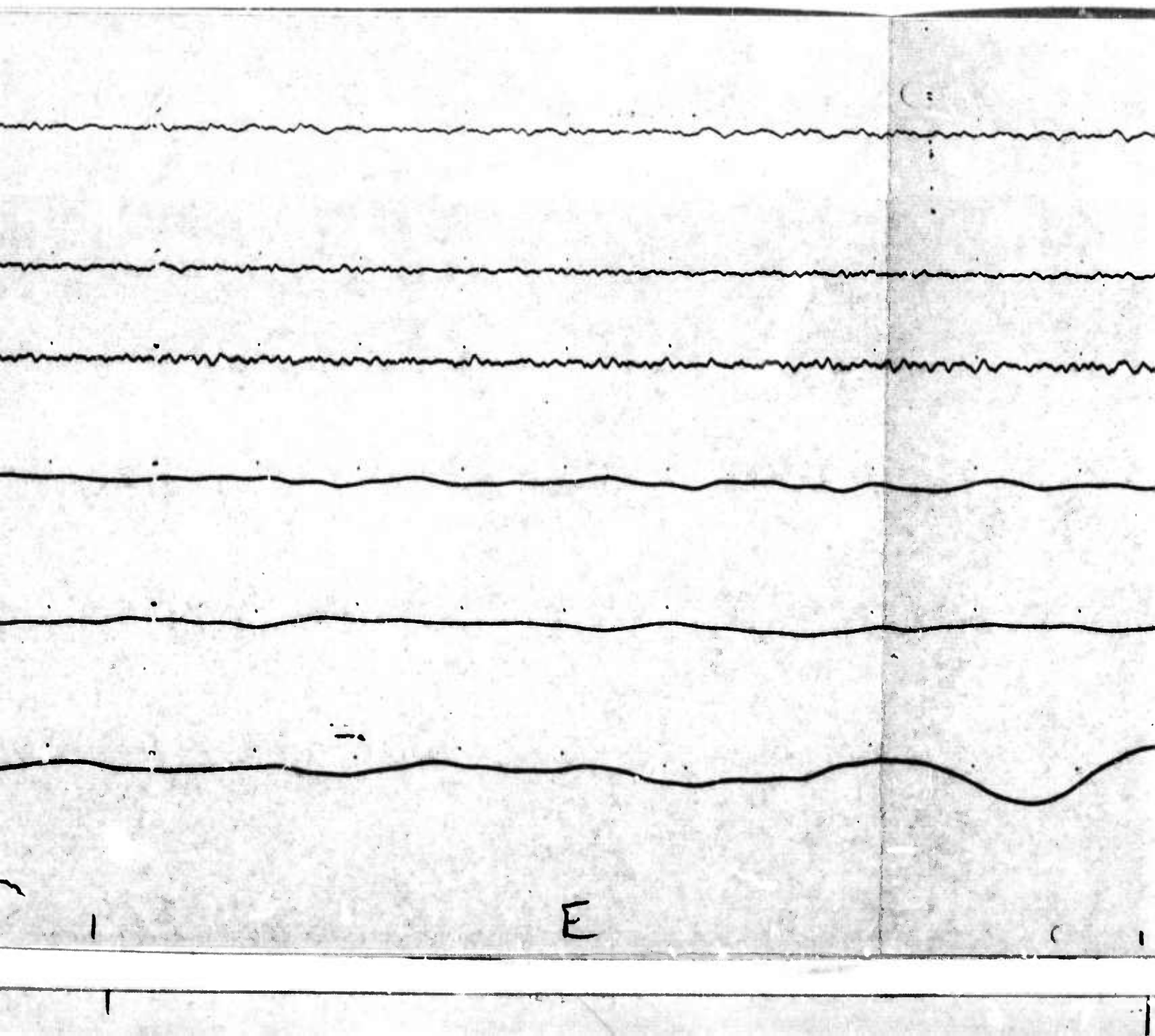
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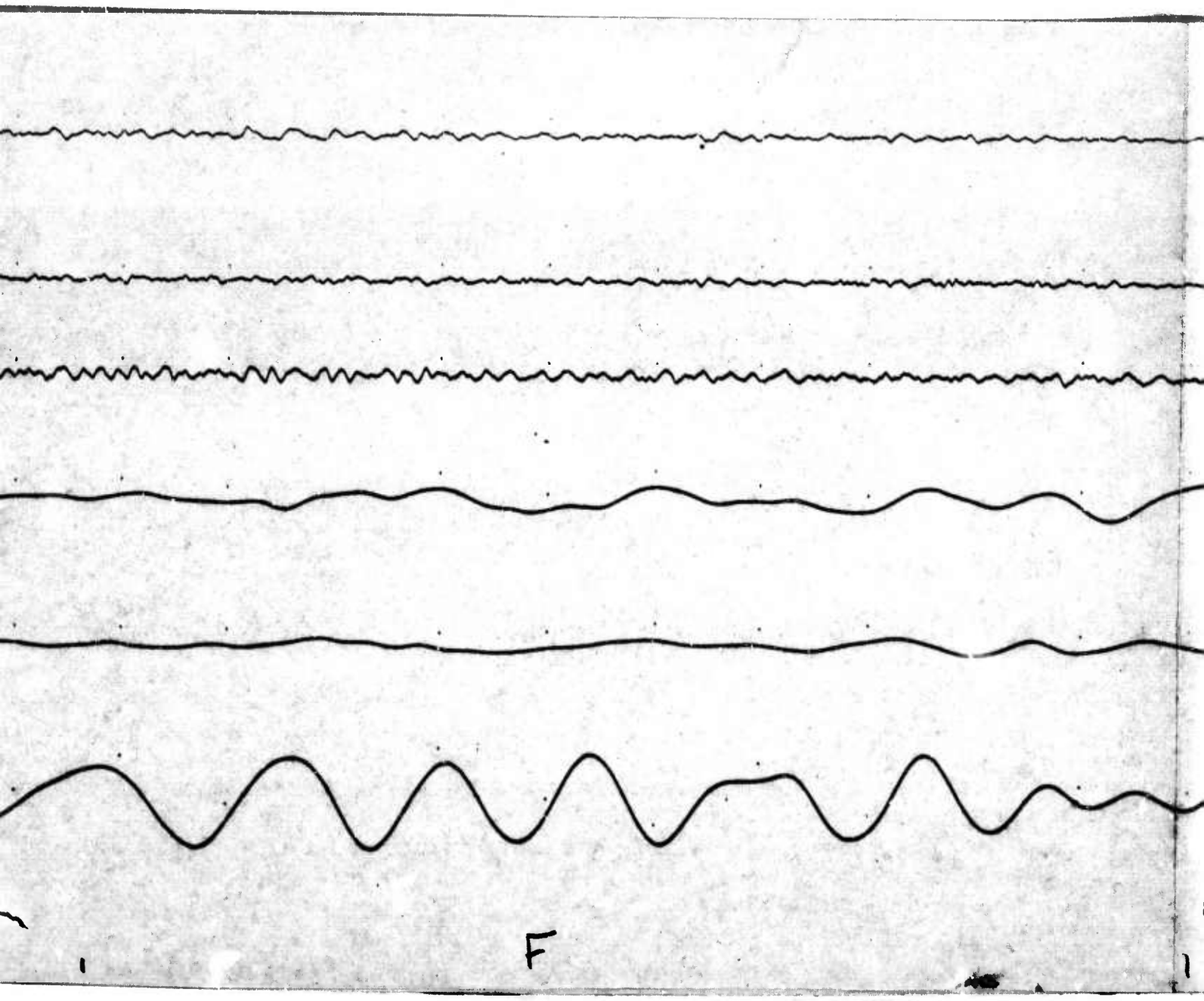
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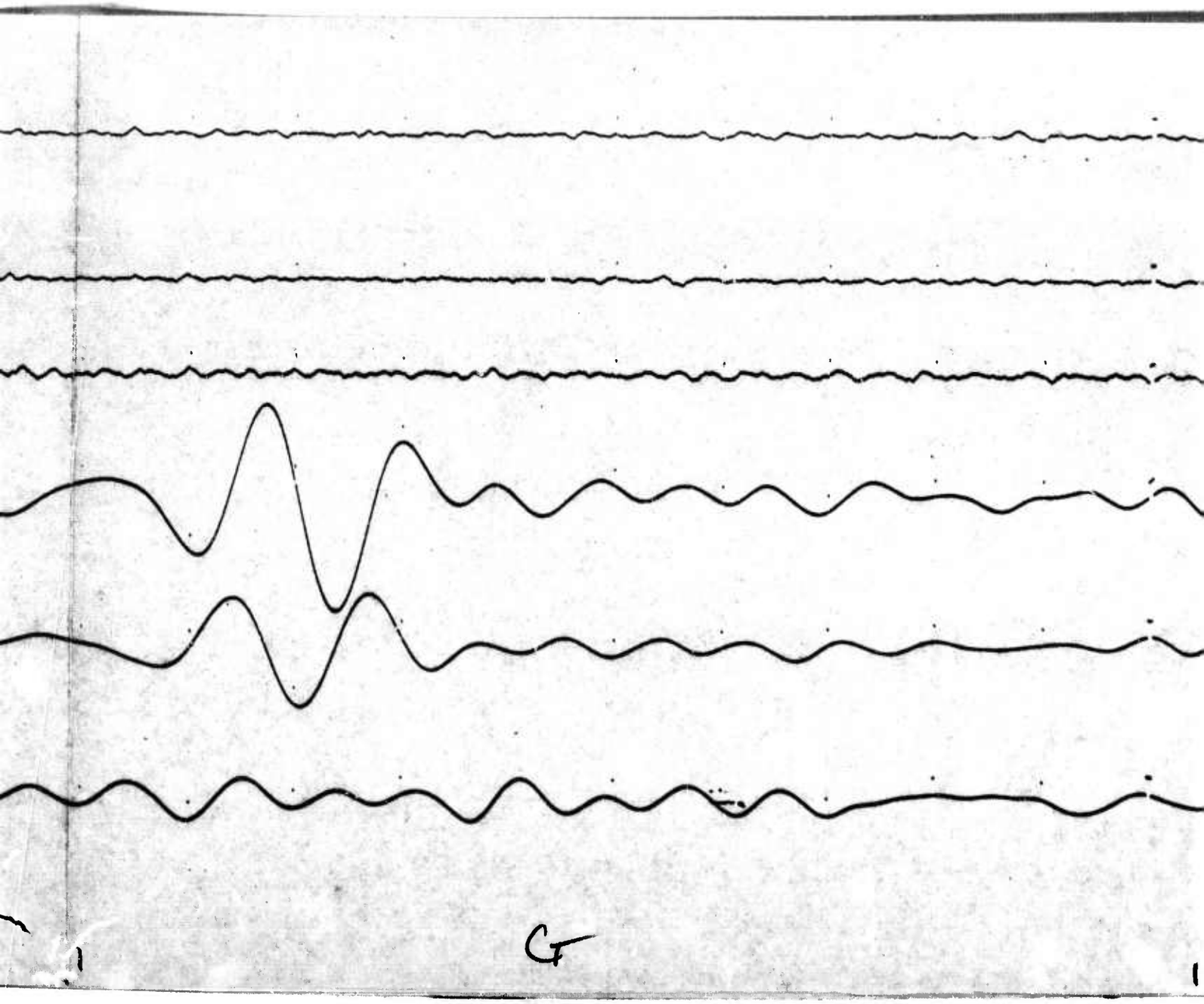
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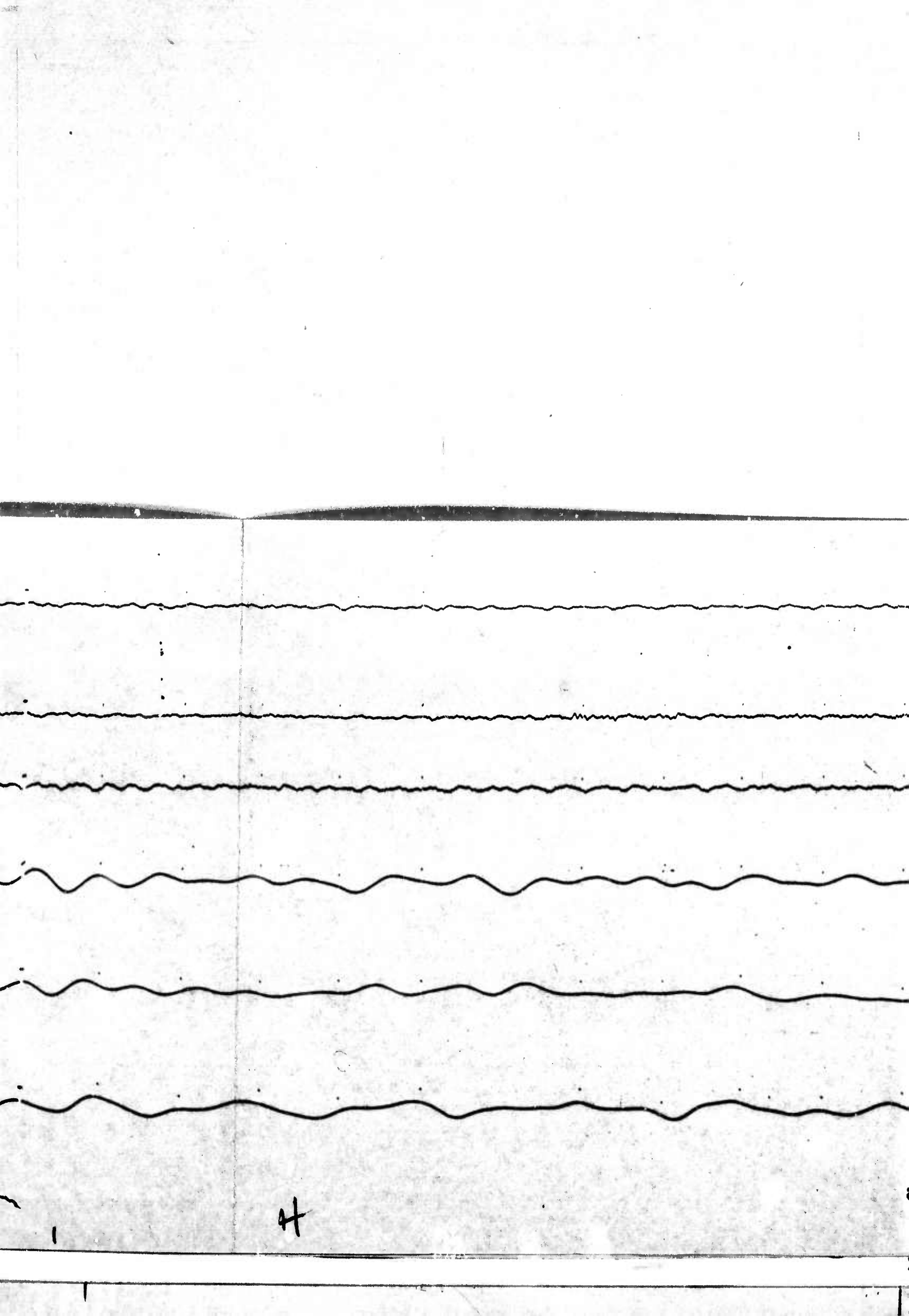
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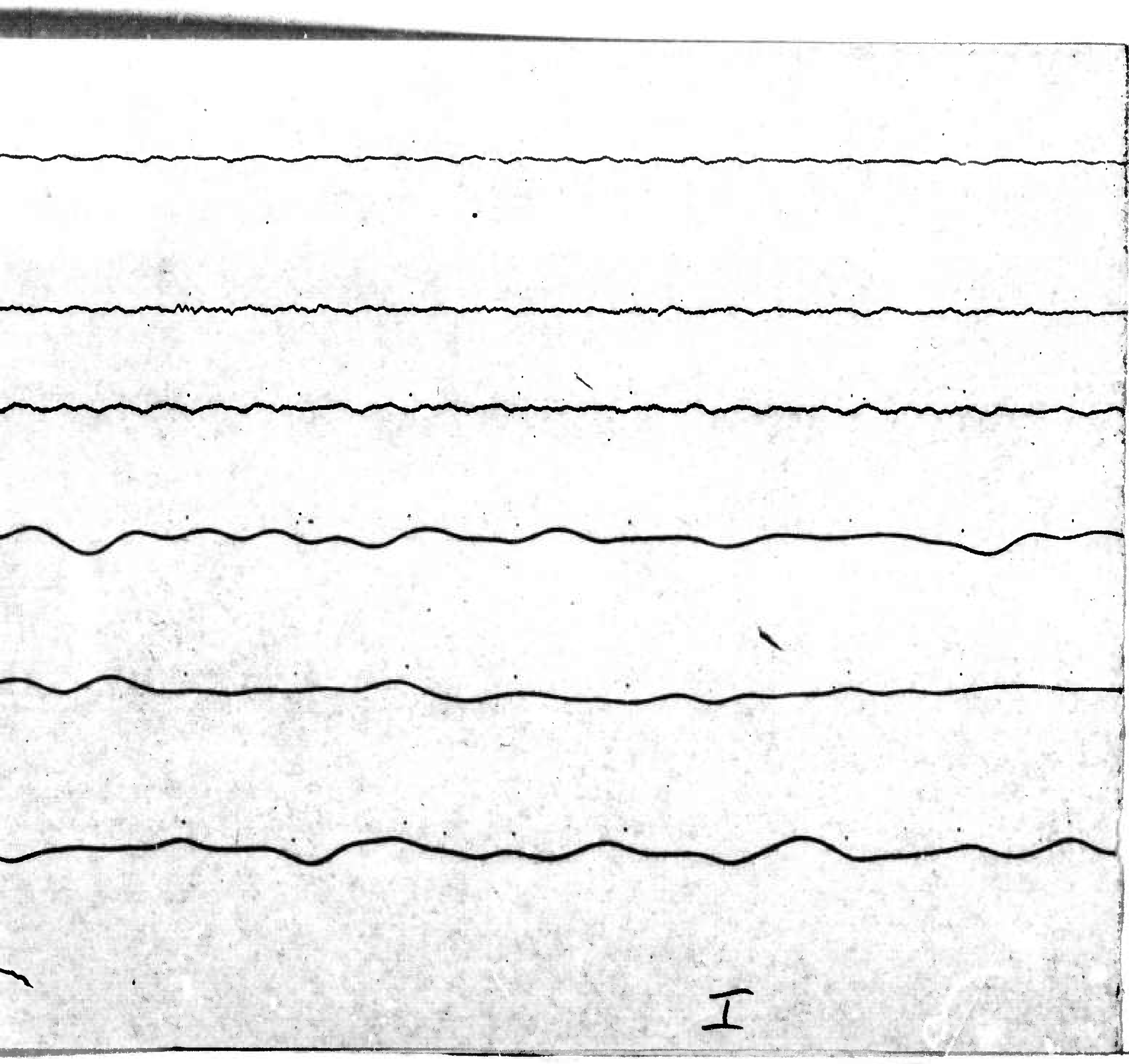

I

KNICKERBOCKER

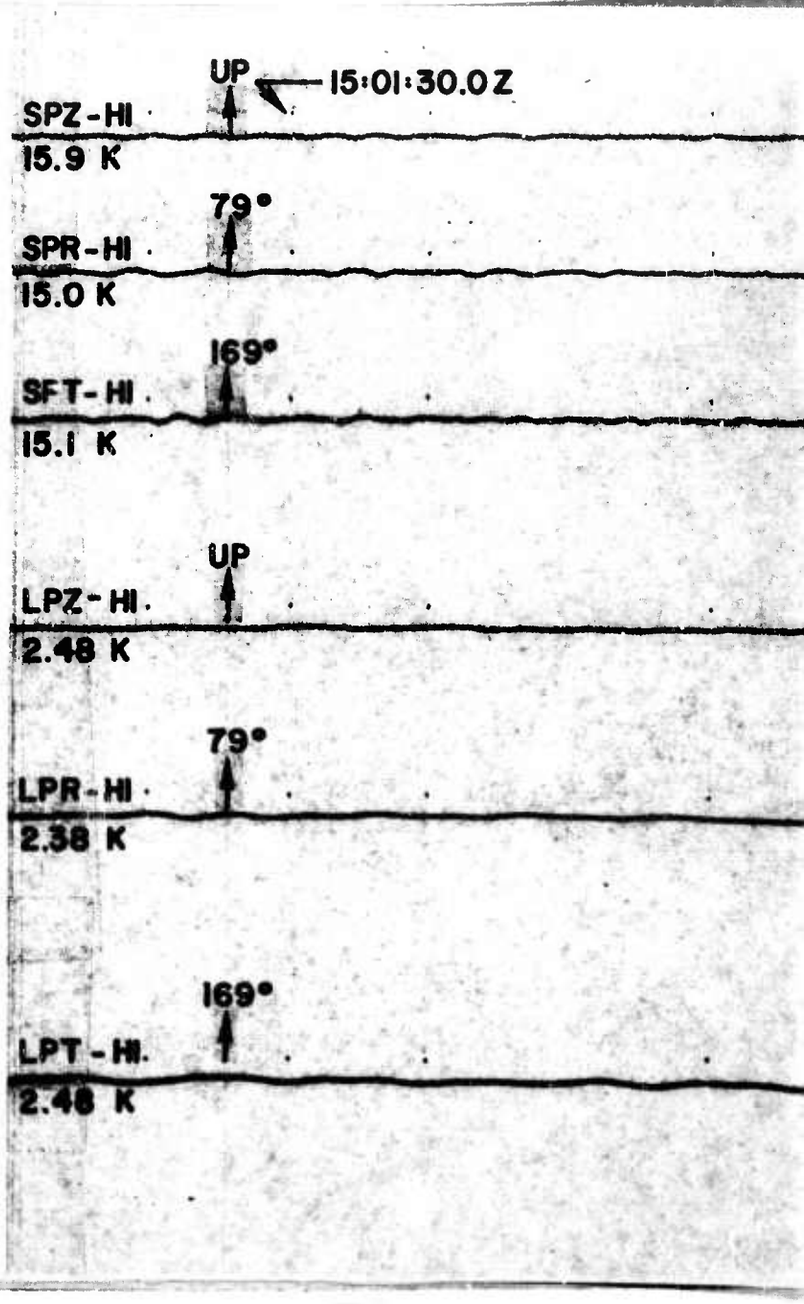
FK-CO

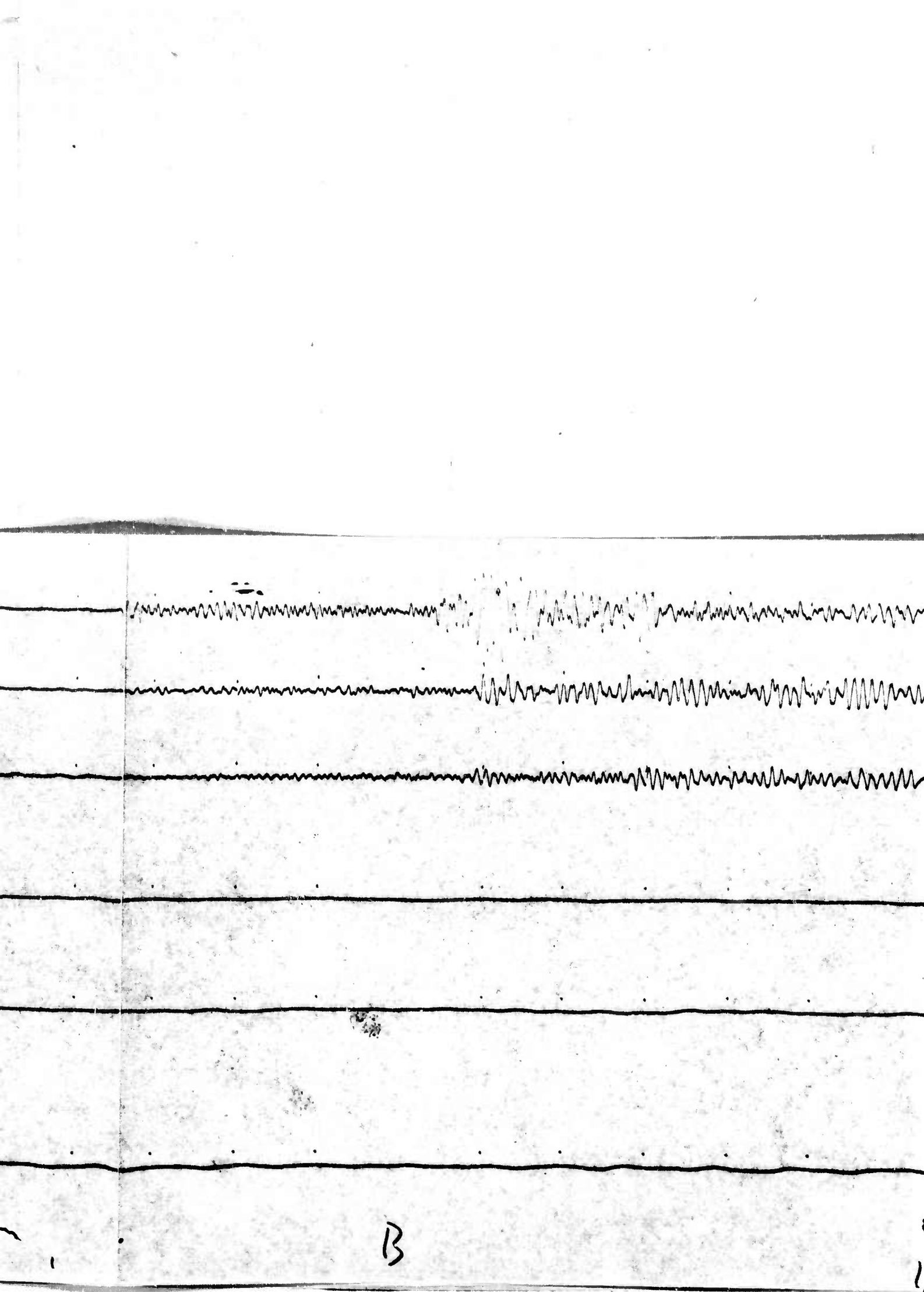
FRANKTOWN, COLORADO

26 MAY 1967

Δ= 1081 km

A

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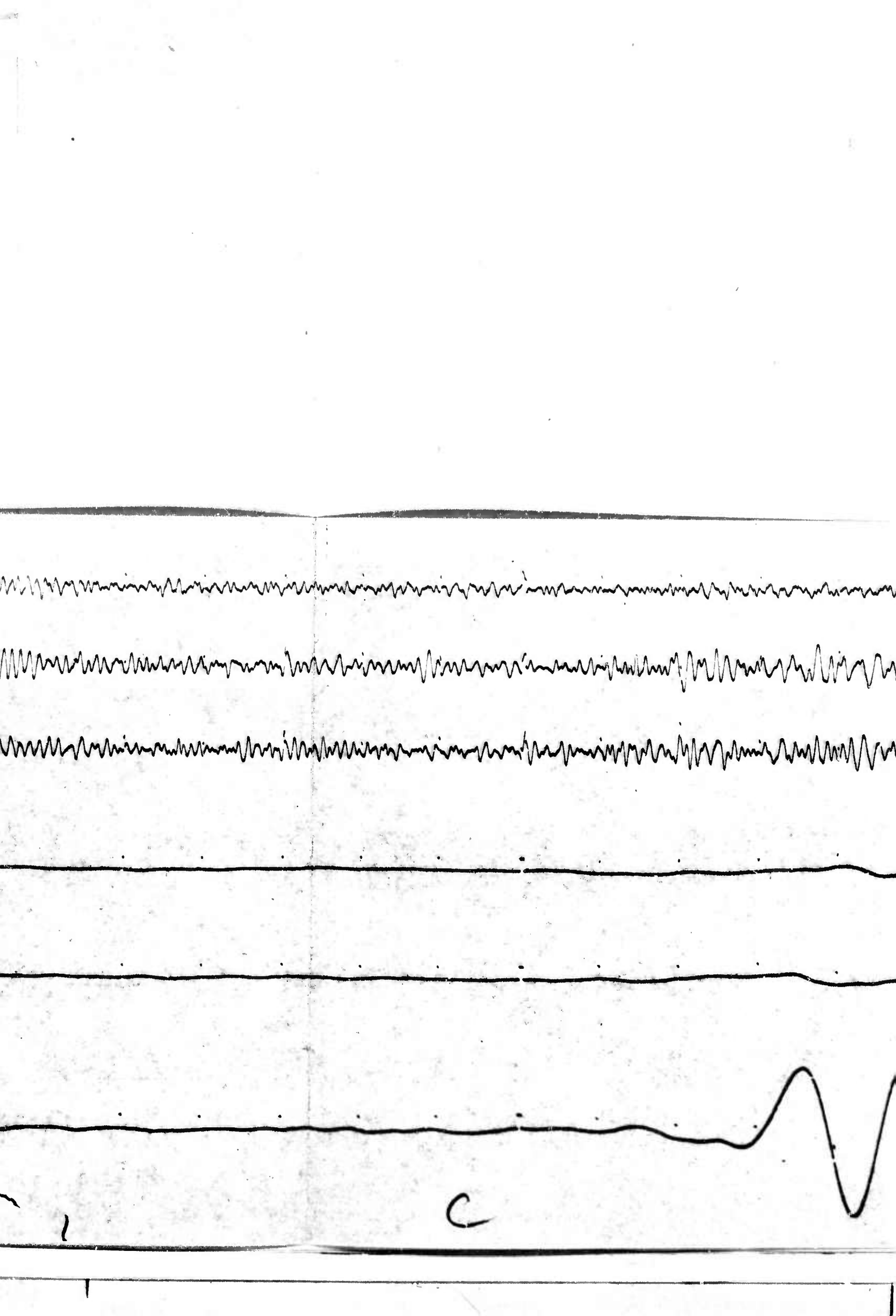
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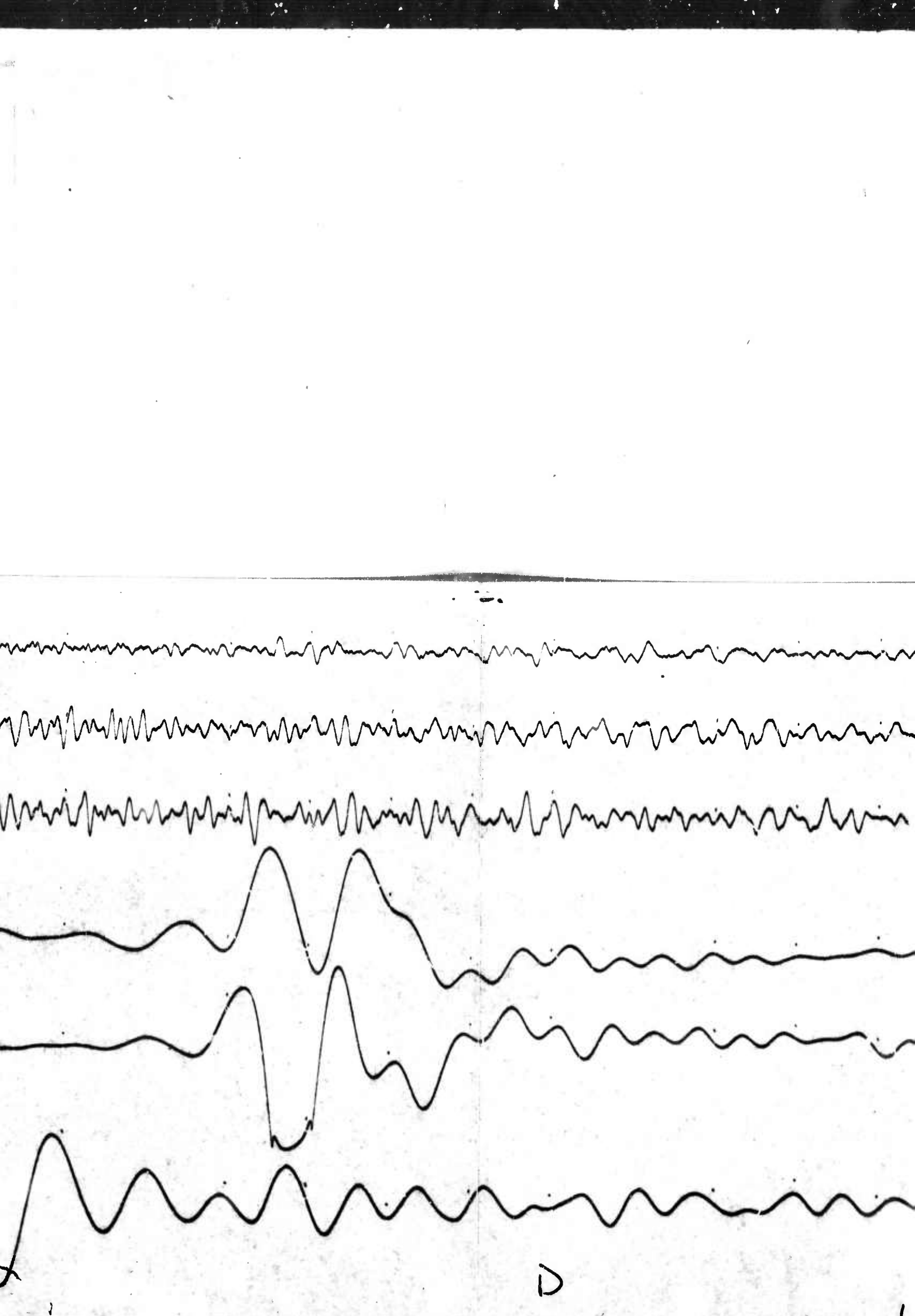
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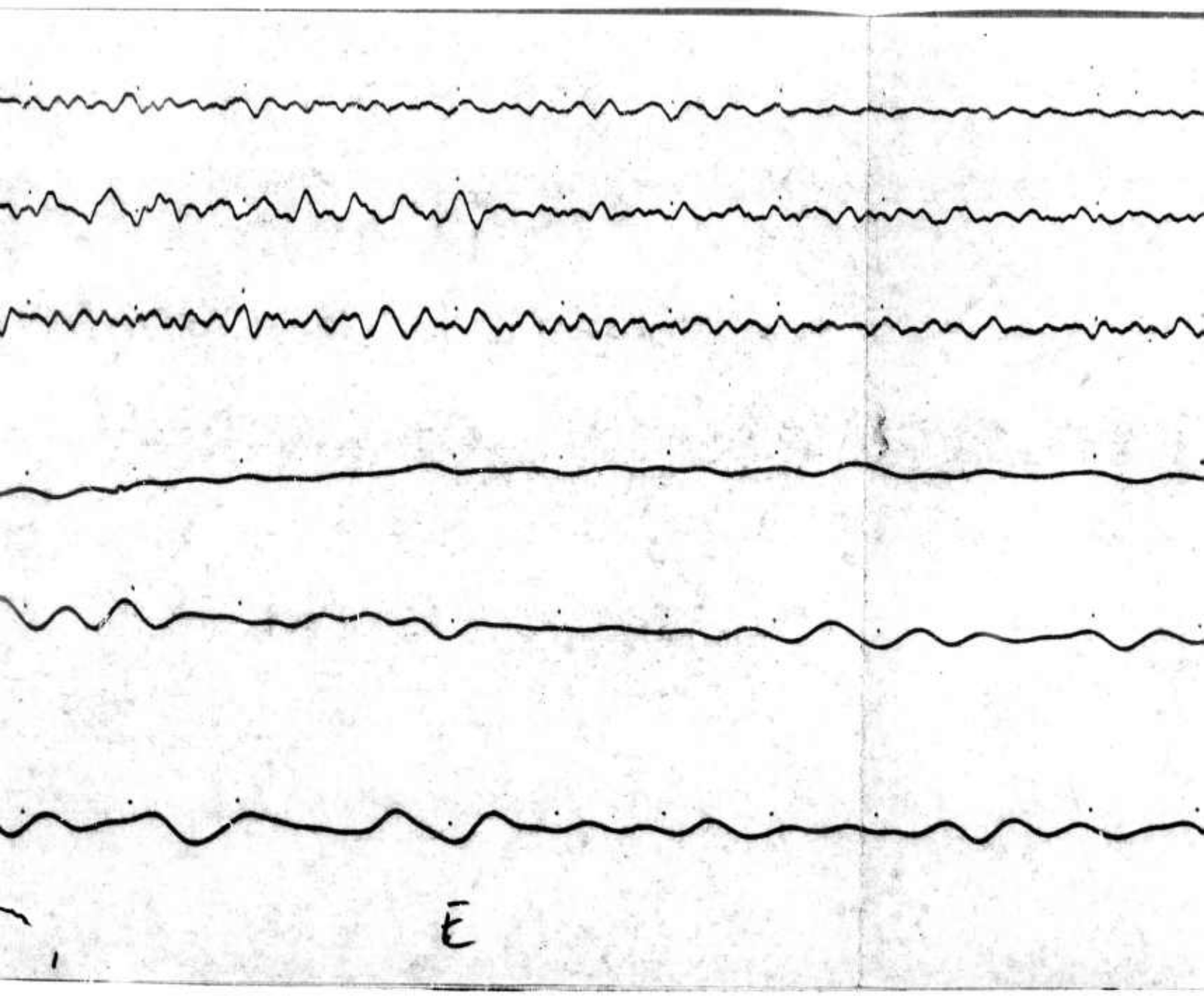
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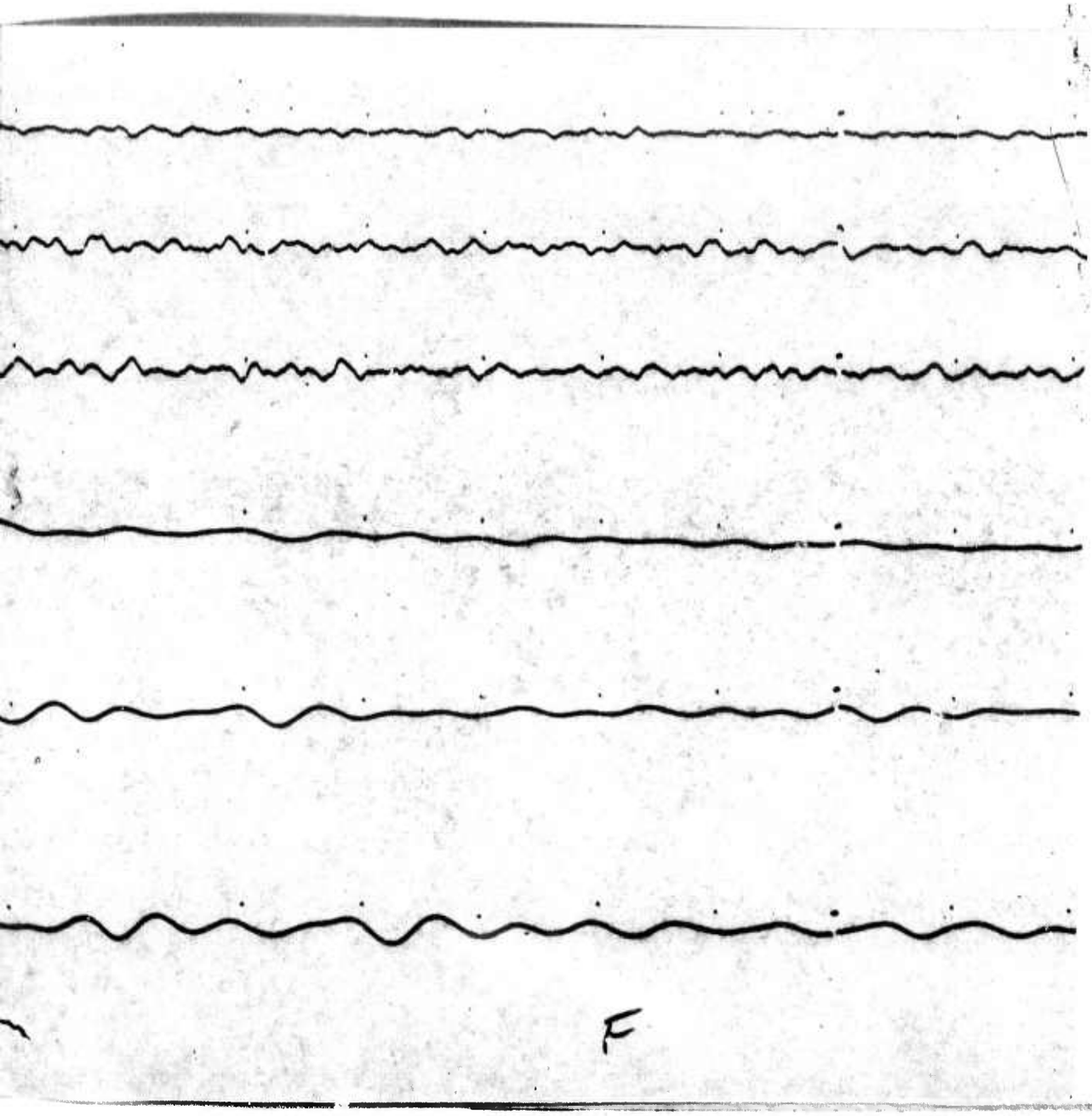
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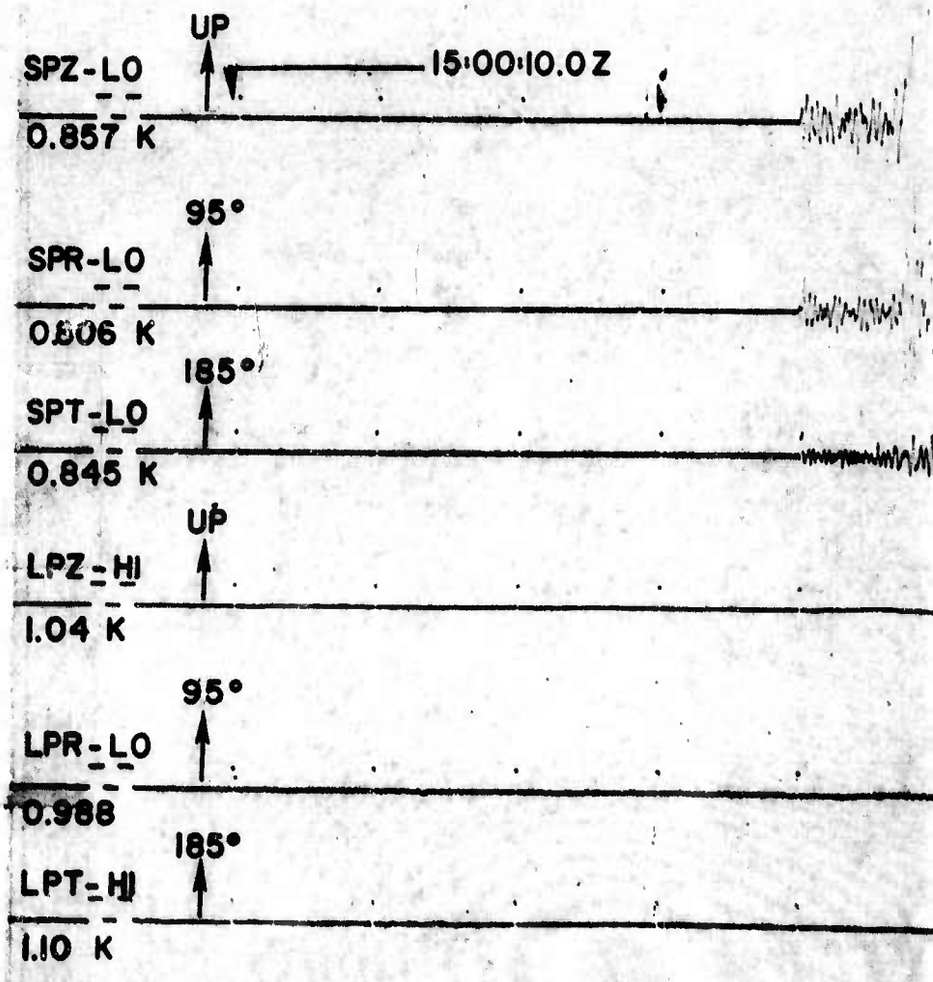
KNICKERBOCKER

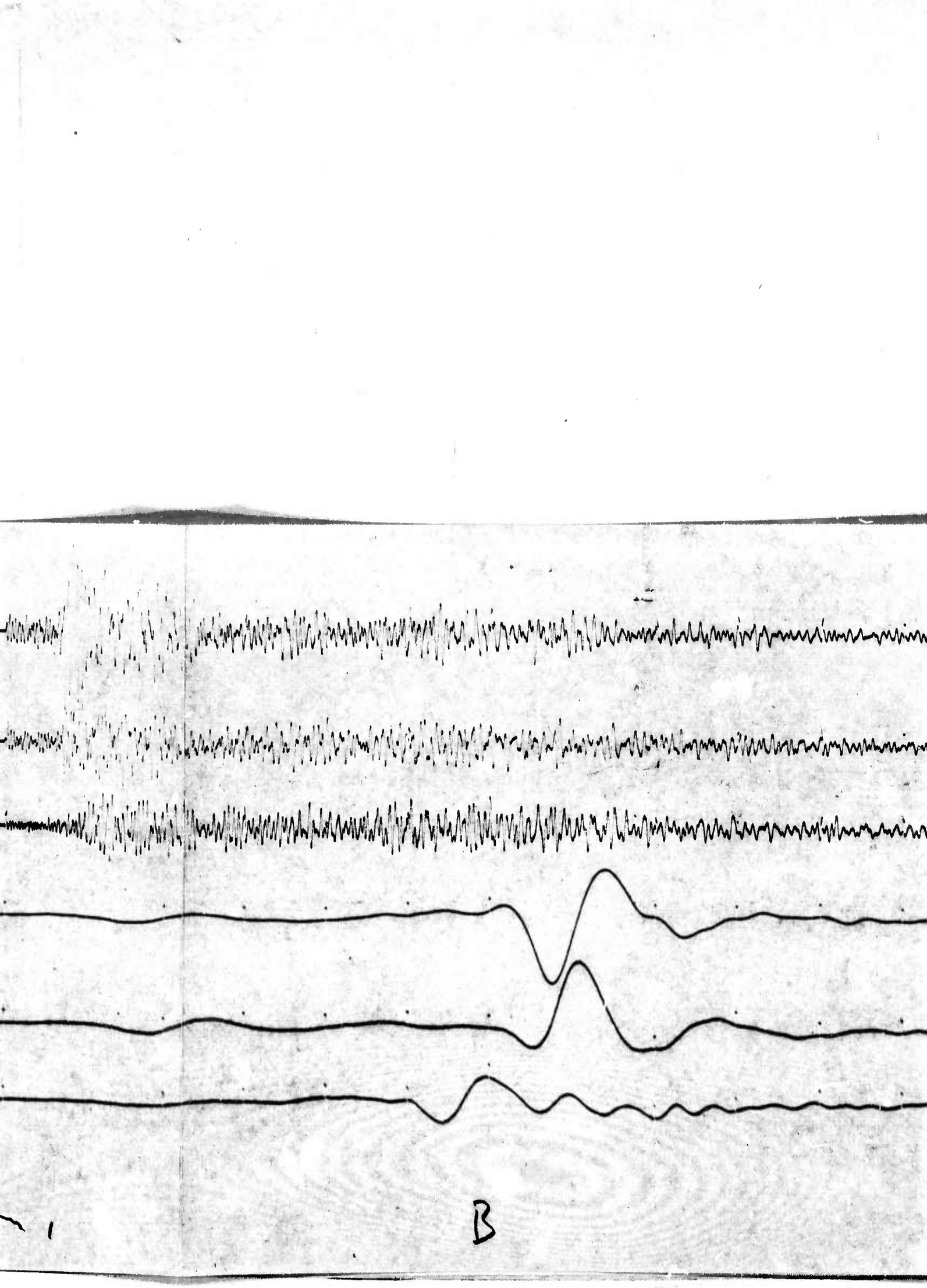
KN-UT

KANAB, UTAH

26 MAY 1967

Δ = 326 km

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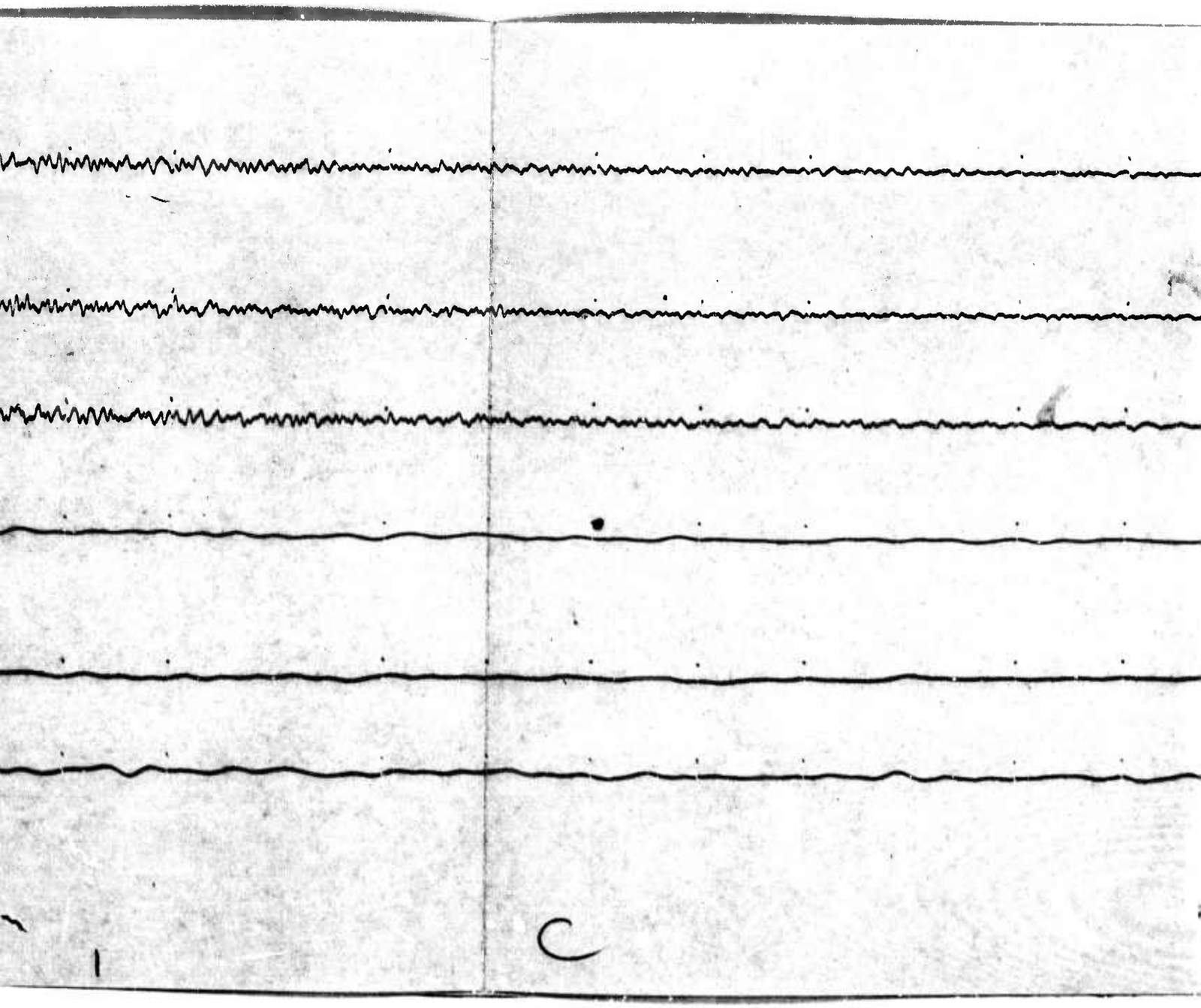

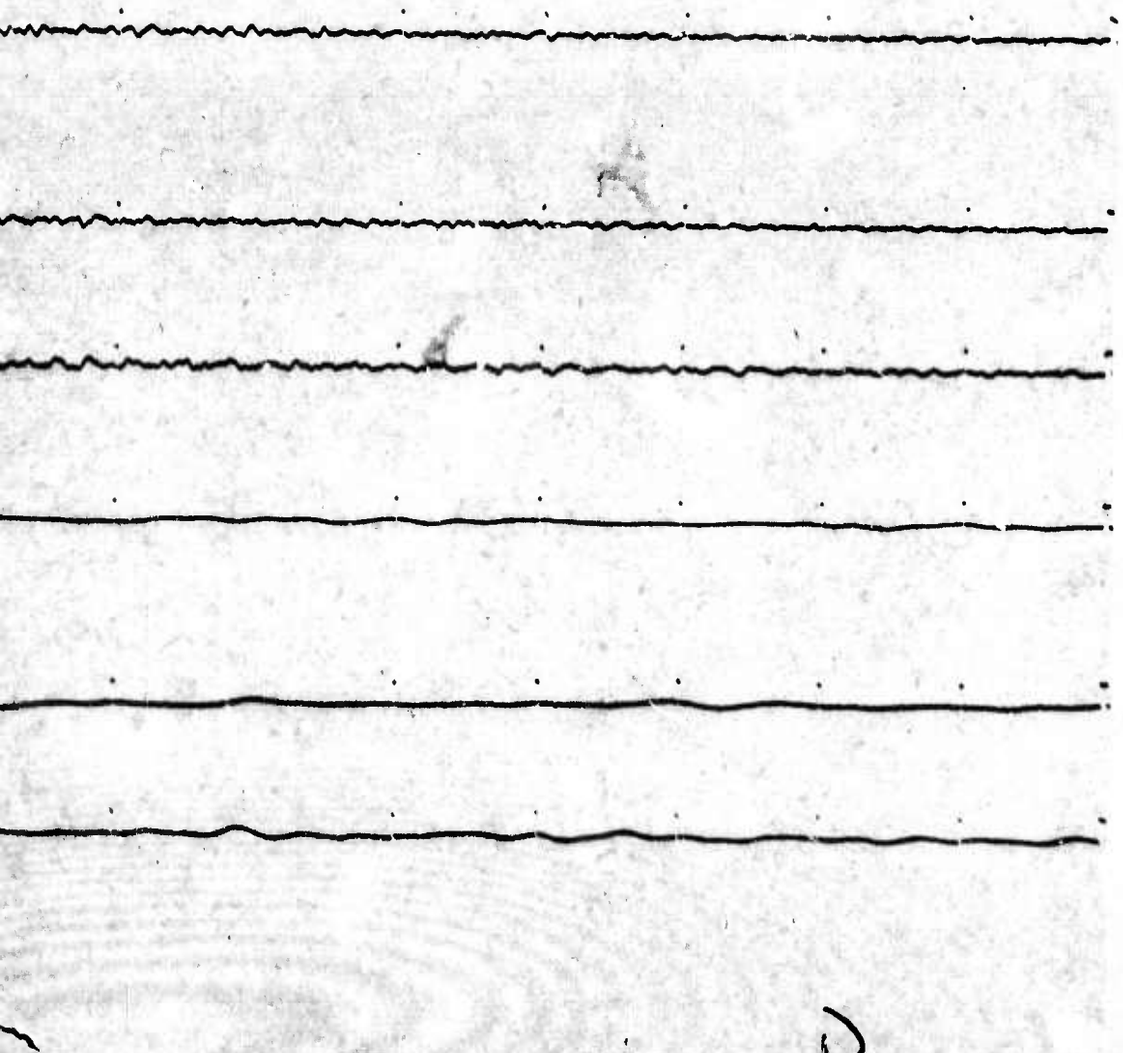

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13. ABSTRACT

An analysis of seismological data from an underground nuclear explosion as a continuing study to provide information to aid in distinguishing between earthquakes and explosions. A table of travel-times and amplitudes of P, Pg, Lg, and surface waves are included along with other unidentified phases.

14. KEY WORDS

Seismic Magnitude
Seismic Travel-Time
Seismic Amplitude
VELA-UNIFORM
Nuclear Tests

Unclassified

Security Classification